Centro de Tecnologia Mineral
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ENVIRONMENTAL AND HEALTH ASSESSMENT IN TWO SMALL-SCALE GOLD MINING AREAS – INDONESIA
FINAL REPORT
SULAWESI AND KALIMANTAN

Saulo Rodrigues Pereira Filho
Project Leader

Ronaldo Luiz Correa dos Santos
Roberto C. Villas Bôas
Zuleica Carmen Castilhos
Allegra Viviane Yallouz
Bernhard Peregovich
Débora Maia Pereira
Flavia M.F. Nascimento
Luiz Roberto M. Pedroso
CETEM

Stephan Boese-O'Reilly
Gustav Drasch
Alexandra Dittmann
Sven Illig
Stefan Maydl
Beate Lettmeier
University of Munich

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Institute of Forensic Medicine, Ludwig-Maximilians University, Munich, Germany

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TECHNICAL FINAL REPORT
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Center for Mineral Technology

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Project Staff

CETEM – Centro de Tecnologia Mineral

Saulo Rodrigues Pereira Filho
Project Leader

Ronaldo Luiz Correa dos Santos
Roberto Cerrini Villas Bôas
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Allegra Viviane Yallouz
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Flavia Maria de Fátima Nascimento
Luiz Roberto Martins Pedroso

University of Munich

Stephan Boese-O'Reilly
Gustav Drasch
Alexandra Dittmann
Sven Illig
Stefan Maydl
Beate Lettmeier

Photos: Dr. Bernhard Peregovich

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Dr. *Gildo de A. Sá Cavalcanti de Albuquerque (in memorian)*
CETEM's Director

Dr. *Christian Beinhoff*
Chief Technical Advisor
Global Mercury Project
UNIDO – United Nations Industrial Development Development Organization

Dr. ***Marcello M. Veiga***
Small Scale Mining Expert
Global Mercury Project
UNIDO – United Nations Industrial Development Development Organization

Dr. ***Fernando A. Freitas Lins***
Focal Point Brazil - Global Mercury Project

Prof. Dr. ***Roberto C. Villas Bôas***
Assistant Focal Point Brazil - Global Mercury Project

Dr. ***Arnaldo Alcover Neto***
Head of Mineral Analysis Coordination

Luiz Roberto Martins Pedroso
Chemist

Flavia Maria de Fátima Nascimento
Hydrogeologist

Sandra Helena Ribeiro, Gaspar Barbosa Alexandre, Jorge Anronio Pinto de Moura, Luiz Fernando M. Bandeira, Jorge Luiz Florindo da Cruz
Analytical Technicians

José Augusto Ferreira Junior
Mineral Technician

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Editing and Coordination of Report Edition

Summary

Executive Summary

The present report describes the results achieved in two small scale gold mining areas in Indonesia, North Sulawesi (Talawaan) and Central Kalimantan (Galangan) - as part of the environmental and health assessment (E&HA) conducted by the Brazilian Centre for Mineral Technology (CETEM) and the German Institute of Forensic Medicine (IFM) of the University of Munich, under the general coordination of the United Nations Industrial Development Organization (UNIDO). The E&HA is a part of the GEF/UNIDP/UNIDO Global Mercury Project - Removal of Barriers to the Introduction of Cleaner Artisanal Gold Mining and Extraction Technologies.

The aim of the subcontract was to undertake two environmental and medical investigations in the Galangan area (Central Kalimantan), and in the Talawaan area (North Sulawesi), both in Indonesia. The ultimate aim of the whole UNIDO project is to reduce mercury losses in the project demonstration sites by means of introducing new technologies, while improving the income of the miners through more efficient recovery, increasing knowledge and awareness, and providing policy advice on the regulation of artisanal gold mining with due consideration for gender issues.

In order to identify sites with high concentration of mercury (hotspots) a sampling campaign of soils, sediments and biota was conducted, consisting of 768 samples. The present report describes results of mercury analyses in sediments, soils, tailings, water and biological indicators, as well as clinical examinations and mercury levels in 500 people living in the Indonesian gold mining areas. An integrated approach has been applied to describe the distribution and behavior of mercury in the environment and its health effects, in order to provide a better understanding of the whole impact caused by mercury emissions and exposure.

A research team comprising 11 research scientists from CETEM (7 members) and IFM (4 members) commenced with the work in Indonesia in August 2003 and accomplished the sampling campaign within 30 days.

Environmental Assessment

North Sulawesi - Talawaan

North Sulawesi is a region of the Sulawesi Island in the Celebes Sea. Manado is the capital of North Sulawesi, and has approx. 600.000 inhabitants.

Manado Bay is surrounded by some famous islands, for example Bunaken Island. Bunaken National Marine park is well known for its beautiful coral reefs, which are a tourist attraction. Three small rivers drain into this bay. They origin from the Talawaan watershed, approx. 20 to 30 km away from Manado.

Tatelu is a small village in the Talawaan watershed with approximately 2.000 inhabitants. Next to the village is the mineral processing area. The ore is excavated in the mountains. A group of 15-20 miners live in very basic camps beside their tunnel.

The study area includes the drainage basins of the Talawaan and Tatelu River. The drainages flow through the main gold processing units where mercury is widely used and released. About one third of the coastline of the area is within the boundary of the Bunaken National Marine Park. The coastal environment includes mangrove areas and coral reefs.

According to Turner (2002), the North Arm of Sulawesi is a classic oceanic island arc that includes porphyry Cu and volcanic-hosted epithermal Au-Ag deposits. The Ratatotok Au district, located 100 km to the Southwest of Manado, is hosted in Miocene carbonate rocks deposited in a Northeastern-trending graben, and covered by andesitic volcanic and volcaniclastic rocks. Carbonates are silicified, decalcified, dolomitized, and have anomalous concentrations of Hg, As, Sb, Tl and low base-metals, as Zn, Cu and Pb (all < 100 ppm). Therefore, one may realize that a naturally anomalous Hg background is to be found in North Sulawesi.

It is estimated that 130 milling operations are working in the Talawaan watershed (Tatelu region). They purchase 10 to 15 kg of mercury/month/milling unit. A unit with 12 mills recovers 4 to 6 g of gold per cycle. Generally there are two cycles per day. The mills operate 8 hours/day, 6 days/week.

Most miners are currently storing amalgamation tailings in plastic sacks to be sold to cyanidation plants. Since a certain portion of the gold is not recovered from the gold ore by the amalgamation process, the wastes of the processing sites are collected in sacks and transported by cars to nearby located cyanidation plants, where the material is chemically processed to extract the gold left in the amalgamation wastes.

According to a mass balance based on both analytical determinations in amalgamation wastes and interviews with the miners, the estimated ratio Hg_{lost} : $Au_{produced}$ in Talawaan falls into the extremely high range of 40 to 60, which is 30 to 40 times higher than average ratios found in SSM worldwide (Veiga and Baker, 2003; Rodrigues-Filho et al, 2004).

Assuming that 9.6 to 14.4 kg of Hg are lost per unit/month, not less than 15 to 22 tonnes of mercury are being released annually in the entire area of Tatelu. This characterizes an alarming mercury burden to the environment in North Sulawesi.

North Sulawesi

Nearly no suspended matter can be found in drainages of the Talawaan watershed due to the „young" nature of the rivers, except in the most dowstream region where a plain supplies the rivers with some silt/clay material. Moreover this scarcity of clay minerals might reflect the young age of volcanic activities, since the volcanic rocks have been exposed to weathering for a relatively short geological time.

Also the extraction process used does contribute to the low contents of suspended sediments found in the region, since most of the tailings are recovered to be reprocessed in the cyanidation plants.

A sampling campaign of soils, sediments, water and biota was conducted in the Talawaan watershed, consisting of 298 samples split into 156 fish samples, and 142 samples of sediments, soils, water, plants and other aquatic organisms, covering the whole study area. The study area was divided into 7 sub-areas from the most upstream are down to the estuary.

The most upstream sampling site is located close to the spring of Talawaan river where no mining activity was reported. Unexpectedly, Hg levels in those samples were 600 times higher than Hg background levels usually found in sediments in tropical regions (Rodrigues-Filho et al., 2004). Mercury levels at the spring of the Talawaan River average 60 μg/g in the sediment fraction < 74 μm (see Figure 16).

A likely explanation for this anomalous Hg level in unaffected sediments is related to the proximity of the inactive volcano of Mount Kablat, whose former activity might have generated the conditions for the formation of gold deposits in the Tatelu region, as well as their associated Hg enrichment. This Au-Hg association has been observed in other similar gold deposits in North Sulawesi (Turner, 2002). Another study on mercury contamination of the Talawaan Watershed also indicates abnormal Hg levels, up to 2.0 μg/g, in sediments close to its spring (Martens, 2000), whereas no information on the target grain size fraction has been indicated. However, further investigations on the mineralogy of these sediments are required to confirm this hypothesis.

The main mining sites are located approximately 5 km downstream close to the confluence of the Tatelu River and the Talawaan River, where a dam reservoir has been built for water supply of rice plantations. At this place an increase of Hg levels in sediments has been observed as a consequence of Hg releases from amalgamation wastes to the rivers. Mercury concentrations reach up to 480 μg/g and average 154 μg/g in the sediment fraction < 74 μm (see Figures 16 and 21).

Mining tailings consisting of amalgamation wastes containing up to 1250 μg/g and an average of Hg concentration of 317 μg/g (see Figures 17 and 21), must be regarded as mining *hotspots*. Obviously, not all of amalgamation tailings are transported to the cyanidation plants, since plenty of them were found all over the river banks. Mercury levels found in tailings of this area are in the same order of magnitude of the values encountered in *mining hotspots* of gold mining sites in Brazil (Rodrigues-Filho et al., 2004).

Further downstream and close to the estuary Hg levels in sediments drop to a mean concentration of 6.7 μg/g, which is even lower than those encountered in the most upstream part of the river, indicating a dilution effect caused by runoff of catchment soils (see Figure 16).

As for the assessment of Hg bioavailability by using bioindicators other than fish, like aquatic plants and mollusks, there is indication that Hg is being taken up by living organisms in the Talawaan River, as shown by the distribution of Hg in aquatic plants and mollusks (see Figures 19 and 20).

Mercury uptake by aquatic plants is particularly evident in cyanidation tailings, where Hg concentrations reach up to 370 μg/g (see Figure 19). This is likely a consequence of increasing Hg mobility and biovailability through the formation of mercury-cyanide complexes after cyanidation of highly contaminated amalgamation wastes.

The mean Hg level in aquatic plants of the Talawaan River, 32.3 μg/g, is 13 times higher than the one observed in the most contaminated SSM site in Brazil, according to a previous study (Rodrigues-Filho et al., 2004).

Mollusks also indicate an abnormally high Hg bioavailability in the Talawaan River, with a mean Hg concentration of 2.6 μg/g (see Figure 20). This mean value is three times higher than the highest Hg concentration found in a previous study on contaminated coastal sites of the USA (O´Connor, 1993).

Therefore, it is assumed that both factors are contributing to the indicated high Hg bioavailability, namely an anomalous Hg background in the area and the cyanidation of amalgamation wastes forming soluble mercury complexes.

A reduced number of water samples were checked for assessing their quality in relation to guidelines for drinking water. At the main mining sites, 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). This is in accordance with the above mentioned hypothesis, since close to the cyanidation plant Hg is clearly forming soluble complexes, becoming therefore susceptible to methylation.

Central Kalimantan (Galangan)

Due to the topographic flat character of the sedimentary basin in the study area of Central Kalimantan (former Borneo Island), its main rivers, Katingan and Kahayan, exhibit a strong meandering stream, while the local wetland in Galangan flows gently to two different river basins, to the Katingan River to Southeast and to the Cempaga River to Southwest.

A 1 km wide forest separates the mining sites from the Katingan River. The mining area consists of a flat plain seasonally flooded, covered by alluvial, Quaternary-Tertiary sediments – mostly sand and gravel with a thicknesss ranging from 2 to 10 m above peaty layers. The occurrence of peaty layers is an indication for a former wetland forest, which now lies some meters above the groundwater table. Therefore, it seems to be very plausible, that the main part of the waters from the mining site soaks into its sediments, before it is drained by means of groundwater run off into the adjacent rivers.

The landscape in Galangan resembles a desert, with some isolated trunks and stumps of giant trees after deforestation of the rain forest. No significant vegetation remained and the soil is reduced to a white, fine sand. The alluvial gold ore deposit consists of a Quaternary-Tertiary (Pleistocene) sedimentary sequence.

Gold mining is carried out following traditional methods also used in the Brazilian gold mining areas (secondary deposits) in the Amazon region. In open pits the gold bearing layers are excavate by a jet of water. The diluted pulp is then pumped to a carpeted sluices box with an inclination of some 15°, in which gold particles are supposed to settle down in the carpet due to their high density. Due to the high turbulence of the pulp flow a considerable part of the gold is lost to the tailings.

Manual amalgamation of the concentrate is done in ponds consisting of flooded open pits excavated beside miners' residences. This practice leads to Hg pollution of the habitat. Amalgam is panned following traditional practice in wooden pans, whereas excess mercury is squeezed through a piece of cloth regaining it for further reuse. All families use water from the open pits for taking bath and washing clothes.

According to a mass balance based on both analysis of amalgamation wastes and interviews with the miners, the ratio Hg_{lost} : $Au_{produced}$ in Galangan is estimated of being in the range of 1.5 to 2, which is an average ratio found in SSM worldwide (Veiga and Baker, 2003; Rodrigues-Filho et al, 2004). Assuming that 150 to 300 g of mercury are lost per unit/month, 1 to 2 tonnes of mercury are being released annually to the entire area.

Amalgam is burned in gold shops, commercial stores in a chimney-like construction, which leads the mercury vapor just outside the house by an outlet pipe. The gold shops are located in the middle of the village. There is no proper ventilation for the mercury fumes, where in the rainy season 15 kg of gold is sold to 20 gold shops and melted in the village, releasing at least 200 kg/annum of mercury in the village. Housing areas, food stalls and a school are just nearby.

According to local authorities about 500 processing units exist in the entire mining area, each one with 4 to 6 miners, who work 10 hours a day, during 6 days a week. Some 3 to 8 g of gold are recovered per unit/day.

A sampling campaign of soils, sediments, water and biota was conducted in the Galangan mining site, Katingan Watershed, consisting of 470 samples split into 264 fish samples, and 206 samples of sediments, soils, water, plants and other aquatic organisms, covering the whole study area, in order to address the identification and location of mercury hotspots.

Mercury concentrations in sediments of the Katingan River are in general significantly lower than in the Talawaan River in North Sulawesi. This is likely related to both a less polluting mineral processing technique used in Galangan and an existing lower Hg background in the Katingan Basin. This is indicated by relatively low Hg levels present in sediments that have been deposited many years before starting SSM activities in the region. Lower sections of sediment cores taken in riversides and floodplains of the Katingan River are assumed to mirror the existing sedimentological conditions prior to the start of the gold rush (see Figure 23).

Distribution of mercury concentrations in a sediment core from the Katingan River, upstream of mining sites, shows significantly lower levels, averaging 0.38 μg/g, than in the cores taken downstream of the mining areas, averaging 2.87 μg/g, 2.19 μg/g and 2.33 μg/g, respectively in sediment cores A301, A501 and A601. Therefore, the Hg range found in core 201 indicates an existing increased Hg background for this study area (see Figures 23 to 26).

Moreover, the sediment cores taken downstream have a similar varying distribution of Hg levels with depth, showing a common peak of Hg concentration between depths from 6 to 12 cm, ranging from 8 μg/g in core A301 to 21 μg/g in core A501, and to 4 μg/g in core 601 (see Figures 24 to 26). This Hg peak is likely related to a major Hg release from the mining sites some years ago that probably mirrors a more intense Hg use at the beginning of the gold rush in 1998.

The distribution of mercury concentrations in individual sediment samples from the Galangan mining site resembles the levels found along the downstream section of the Katingan River, as presented in Figure 27. This a clear indication that sediments from both the mining site and the lower Katingan River are closely related to each other as a consequence of mercury discharges from SSM operations.

Nevertheless, those Hg concentrations in the Galangan region are at least one order of magnitude lower than in the Talawaan region.

The prevailing sandy composition of the mining tailings that is driven by the type of alluvial deposit with almost no silt-clay fraction is a likely explanation for the relatively low levels, since Hg released during amalgamation finds no particulate surface to be adsorbed on, leading to Hg concentrations even lower than in river sediments (see Figure 28).

On the other hand, although a relatively moderate Hg contamination degree in amalgamation tailings is to be reported for Galangan, there are strong indications that mercury finds a favorable condition for becoming highly mobile as indicated by the abnormally high levels found in the organic fine cover of the tailings, composed basically of algae. This is an indication that mercury is being dissolved by the organic dark waters of Galangan, which is a potentially favorable condition for increasing mercury bioavailability through methylation (see Figure 28).

Mercury in Fish – North Sulawesi and Central Kalimantan

The occurrence of fish was investigated in 7 sub-areas, in the Talawaan mining area, North Sulawesi. Along the Talawaan River, 156 fish specimens of 11 species were collected (gabus, gete-gete, gold fish, guruo, kesa, lalimata, mujair, nilem, payanka, sepot, supit), one specimen (gold fish) from fish-farming, while 26 specimens of 5 marine species were bought at the fish market in Manado (cakalang, deho, tudê, bobara and malalugis).

In Central Kalimantan, 264 fish specimens of 25 species (banta, baung, bawal, darap, gabus, gold fish, gurame, juah, kalatau, kalui, kapar, karandang, kelabau, lais, lais lintang, lawang, nilem, papayu, patin, putin, saluang, sapat, tahuman, tekung, tongkol) were collected. Five specimens of five species were bought at the fish market in Palangkaraya. It is important to realize that some specimens came from fish farming inside the Katingan river, such as patin and tahuman species.

The present results show that total mercury concentrations in fish from North Sulawesi are higher than in fish from Central Kalimantan area and the Table 6 shows the minimum and maximum values for Hg in fish in both areas. The resulted mean of Hg from Central Kalimantan is 0.21±0.36 μg/g (N=264) and its maximum value is 1.83 μg/g, while in North Sulawesi mean Hg level is 0.58±0.45 μg/g (N=130) and its maximum value reaches 2.60 μg/g.

It is well known that freshwater biota is able to accumulate Hg from natural and anthropogenic sources. Maximum background levels for Hg in uncontaminated freshwater fish are in the range of 0.1 to 0.3 μg/g, although considerably higher levels can be found in large predators.

The mean concentration of Hg (0.36 μg/g) in fish species from this work was within that range and lower than 0.5 μg/g, the Hg concentration in fish recommended by WHO (1990) as limit for human protection by Hg exposure by fish consumption. However, we have to take into account that these species are smaller and lighter than fish from other aquatic systems influenced by gold mining, such as Amazon region (CETEM/IEC, 2004). In addition, among the analyzed fish, 81 specimens, 21% of total fish sampled (389 fish) presented Hg concentrations above 0.5 μg/g. Whereas in Central Kalimantan less than 10% of fish samples showed Hg levels above that limit, in North Sulawesi this percentage amounted to more than 45%. It should be considered that fish from North Sulawesi are smaller and lighter than fish from Central Kalimantan, suggesting that Hg bioavaliability in Manado can be higher than in Central Kalimantan.

In North Sulawesi, Hg levels in fish from Toldano river (reference area-T6) showed the lowest mercury levels, averaging 0.02 μg/g, while T2, a dam reservoir close to the mining sites, showed the highest mercury levels in fish, 0.85 μg/g being considered as the most contaminated site in the area. The Hg levels in the reference site are quite low, although they are from the hydroelectric power plant lake, mentioned, sometimes, as an environment that may show high mercury methylation rate.

In Central Kalimantan area, fish from flooded open pits in mining site areas showed the highest Hg levels. These open pits are used for gold processing and, also, for fishing, bathing and domestic wastes collected. While the average of Hg in fish from the whole study area are quite low, the Hg levels in fish from the flooded open pits in the small-scale mining area are considered as the most contaminated sites. As miners and their families are living close to those open pits and might often consume those fish, this characterizes a potential pathway for methylmercury exposure to the local population.

By employing a risk assessment to human health, toxicological, rather than simply statistical, significance of the contamination can be ascertained. At a screening level, a Hazard Quotient (HQ) approach (USEPA, 1989), assumes that there is a level of exposure (i.e., RfD = Reference of Dose) for non-carcinogenic substances below which it is unlikely for even sensitive populations to experience adverse health effects. The MeHg RfD value is 1E-04 mg.Kg-1.d-1 (IRIS 1995) and its uncertainty factor is 10 and its confidence level is medium. Uncertainties of the RfD statistics have been reported, suggesting an under-estimation of RfD for Hg presented in IRIS, 1995 (Smith and Farris 1996). However, other authors suggest that there is no safe human exposure to MeHg and that of all living species, human appear to have weakest defenses against MeHg (Clarkson 1996). Considerable gaps in our knowledge about this remain.

Our approach, therefore, is to use the human risk assessment proposed by USEPA, at a screening level. HQ is defined as the ratio of a single substance exposure level (E) to a reference of dose (E/RfD). When HQ exceeds unity, there may be concern for potential health effects. The estimated exposure level was obtained by multiplication of 95th percentil upperbound estimate of mean Hg concentration considering all fish as suggested by USEPA (1989), by the adult human ingestion rate for local populations. Most of the works about riverside population assume consumption rate close to 0.2 Kg.d-1.

As a matter of fact most people in North Sulawesi consume fish from the market, mainly marine fish or freshwater from fish farming, rather than those small fish from the study sites.

In Central Kalimantan, it should be taken into account that miners living close to the P4 study site may consume fish caught in flooded open pits. As they are not a riverside population, but considering the poverty, one could assume that the fish consumption rate close to 0.05 $Kg.d^{-1}$. Finally, the intake dose is estimated by dividing that product by 70 kg, considering an average weight of a human adult. Although total mercury was quantified in fish, it has been demonstrated that about 75-95% of total mercury is methylmercury in fish muscles. Thus, in a conservative approach, it has been assumed that total mercury in fish represents methylmercury. The resultant HQs for MeHg fall above the unit for North Sulawesi considering the fish market consumption. For Central Kalimantan, both total and P4 sampling site, HQ resulted above the unity, 2.4 and 9.9, respectively, which means that the population is subject to potential health hazards due to fish consumption. This conclusion is fully in agreement with indications of mercury exposure achieved by the health assessment.

Health Assessment – North Sulawesi and Central Kalimantan

There is no clean and safe drinking water, no waste disposal for the toxic mercury or any other waste or human discharge in both study areas. Hygienic standards are extremely low and are a reason for many infectious diseases such as diarrhoea, typhoid and parasitism.

Road accidents, accidents in insecure tunnels and amalgamation plants, malaria, tuberculosis, and sexually transmitted diseases are the dominant causes of morbidity and mortality. HIV seems to increase within the mobile men with money ("MMM") subgroup, esp. single male miners. But no accurate data on the incidence of AIDS exists. Smoking is a very common, unhealthy habit of the men.

The health centre in Kereng Pangi and Tatelu are able to offer some basic, but adequate health services in the area. But they are not equipped for the occupational health hazards in gold mining areas (accidents, mercury).

The extraction of the gold with liquid mercury releases serious amounts of mercury, especially high toxic mercury fumes into the local environment. The health status of 492 volunteers in Sulawesi and Kalimantan was assessed with a standardised health assessment protocol from UNIDO (Veiga 2003) by an expert team from the University of Munich/Germany in August/September 2003. 23 people had to be excluded from the further statistical evaluation due to neurological diseases or their age. 222 people come from Sulawesi, and 247 from Kalimantan (see as also Table 5).

For statistical purposes a control group was selected in Air Mandidi (Sulawesi), the adults and children there showed low levels of mercury in all bio-monitors and a low medical score, indicating that they were not exposed to mercury (see Figure 3, 5, 7). In Kalimantan a control group, mainly women were selected approx. 35 km away in Tangkiling, a village situated at a different river system. The urine levels of this group were low during the analysis, performed during the field project. The urine levels were confirmed in the later re-analysis in the University laboratory (see Figure 4). But unexpectedly the blood and hair analysis showed increased levels of mercury in these participants (see Figure B6 and 8). Nevertheless, this is in accordance with the indications from the environmental assessment, namely a elevated Hg background in sediments, a reatively high Hg mobility and a high Hg biovailability, which is likely related to existing dark water rivers in the area.

The medical score sum between the control group in Sulawesi, and the group in Tangkiling also differs (see Figure 18 and 19). Fish eating habits contribute to the internal exposure leading to the hypothesis that the population in Tangkiling is exposed through fish from the local river (see Figure 9, 10. 11). For the statistical analysis Tangkiling was considered to be another exposed area, and only the control group from Air Mandidi (Sulawesi) was used for all statistical comparisons.

The mercury levels in the bio-monitors urine, blood and hair were significantly higher in all exposed populations than in the control group (see Figure B3 to B10). Mainly amalgam-smelters showed mercury levels above the toxicological threshold limit HBM II in urine, blood and hair. Mainly inorganic mercury contributes to the high body burden of the workers.

Some few cases, all from Galangan in Kalimantan, showed extreme high mercury concentrations in blood and extreme high concentrations of organic bound mercury in hair. This may be explained by fishing in heavily mercury contaminated pit holes in this mining area, as observed from the results of Hg in fish from the flooded open pits.

Typical symptoms of mercury intoxication were prevalent in the exposed groups. The medical score sum plus the bio-monitoring results made it possible to stablish in Tatelu (Sulawesi) in 33 out of 61 amalgam-smelters the diagnosis of a chronic mercury intoxication, and in 4 out of 17 mineral processors. Within the other population in Tatelu 2 out of 18 people showed a mercury intoxication. In the control group there was no case of a mercury intoxication.

In Kereng Pangi (Kalimantan) in 41 out of 69 amalgam-smelters the diagnosis of a chronic mercury intoxication was made, and in 13 out of 30 mineral processors. Within the other population in Kereng Pangi 23 out of 67 people showed a mercury intoxication. In the Tangkiling group 8 out of 36 people were found to be intoxicated, and 4 out of 10 former miners.

Children working with mercury were found as intoxicated in 9 out of 51 children in Tatelu, and 2 out of 8 children in Kereng Pangi. Children not working, but living in the exposed areas were intoxicated in 5 out of 27 cases in Kereng Pangi and in no case in Tatelu. None of the children from the control area are intoxicated.

The percentage of intoxications among amalgam-smelters is similar in Tatelu (54,1%) and Kereng Pangi (59,4%). In Rwamagasa / Tanzania 25,3% of amalgam smelters were found to be intoxicated, and in the gold mining area of Mt. Diwata in the Philippines, 85.4 % of the amalgam-smelters were intoxicated (Drasch 2004b, Drasch 2001). The difference cannot be explained by a different, i.e. a safer burning technique in Rwamagasa. Moreover, it must kept in mind, that the maximal burden (as expressed in the top mercury concentrations found in the bio-monitors) was even higher than in Mt. Diwata. In the less exposed population and the children, the rates of intoxication are much higher in Kereng Pangi.

An explanation for these differences cannot be found only in the amalgam smelting techniques. The main difference between Tatelu and Kereng Pangi is, that in Tatelu the general population does not live within the mining area itself, so they are less exposed. And the difference to Mt. Diwata is that the Galangan area around Kereng Pangi is flat compared the mountainous area of Mt. Diwata. The difference to Tanzania might be explained by the much lower exposure to liquid mercury in Rwamagasa, due to a lower output of gold from the ore.

Child labour in the mining sites is very common from the age of 10 years of age and upwards, the children work and play with their bare hands with toxic mercury. Mercury can cause severe damage to the developing brain. It is a dramatic outcome, that already 17,6% of the children working with mercury in Tatelu and 25% of the children working in Kereng Pangi with mercury, respectively 18,5% of the children living in Kereng Pangi, had a mercury intoxication. E.g. in Kereng Pangi some gold-smelting shops (Toko Mas) are situated opposite the mosque and one school.

Nursed babies of mothers living in Kereng Pangi are at special risk. In 10 out of 15 breast-milk samples of nursing mothers, mercury levels were above comparison levels of 2 µg/l. In two cases the levels were extremely high, well above reference dose levels of US-EPA.. In addition to a placental transfer of mercury during pregnancy from the mother to the foetus (as has been proved in other studies) this high mercury burden of nursed babies is a new, up to now unknown health hazard in mining communities.

Poverty is a main reason for the bad health status of the small-scale mining communities. Struggling for pure survival makes mining for gold a necessity to find any financial resource. The daily fight of survival forces the miners put their own health and the health of their children at risk.

A reduction of the release of mercury vapours from small-scale gold mining as in Indonesia into the atmosphere will not only reduce the number of mercury intoxicated people in the mining area proper. It will reduce the global pollution of the atmosphere with mercury, because most of the mercury vapour formed by the open burning of gold amalgam is not deposited locally, but is transported by air over long-range distances all over the globe (Lamborg 2002). The total release of mercury vapour from gold mining is estimated today up to 1,000 metric tons per year (MMSD 2002), while from all other anthropogenic sources approximately 1.900 tons were released into the atmosphere (Pirrone 2001).

The primary result is, that mercury is a serious health hazard in the small-scale gold mining areas of Tatelu (Sulawesi) and Kereng Pangi (Kalimantan). Working for many years in the amalgamation or burning process, especially amalgam-burning resulted in severe symptoms of mercury intoxication. The exposure of the whole community to mercury is reflected in raised mercury levels in the urine, and symptoms of brain damage like ataxia, tremor and movement disorders. In over 50% of the amalgam-smelters from both areas a mercury intoxication (according to the definition of UNIDO (Veiga 2003)) was diagnosed. Former miners, mineral processors and the general population in the mining areas were also intoxicated. Especially frightening are high levels of mercury in breast milk samples in Kereng Pangi (Kalimantan), and the high incidence of child labour. This high incidence of child labour ensues in the very early child mercury intoxication in both areas.

The background burden in the control group in Air Mandidi (Sulawesi) is in the same order of magnitude as in western industrial countries.

Although mercury is heavily burdening the environment in North Sulawesi, health hazards due to methylmercury exposure, as indicated by results in fish, hair, blood and breast milk, are more likely occurring in Central Kalimantan. This may be explained by a combination of factors, namely the adverse living conditions in Galangan that make the population dependent on fishing in flooded open pits; a high mercury bioavailability in dark water systems, and an increased mercury background in the local environment, as indicated by the environmental assessment. In contrast, there is a lack of pathways between methylmercury present in the environment and the local population in North Sulawesi, since the availability of fish in the Talawaan River is very limited, resulting in consumption from marine fish. On the other hand, 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, taken up by the marine biota occuring in the Manado Bay.

1. Introduction

The present report describes the results achieved in two small scale gold mining areas in Indonesia – in North Sulawesi and Central Kalimantan - as target areas of the environmental and health assessment (E&HA) conducted by the Centre for Mineral Technology (CETEM) and the Institute of Forensic Medicine (IFM-University of Munich) under the general coordination of the United Nations Industrial Development Organization (UNIDO). The E&HA is a part of the GEF/UNIDP/UNIDO Global Mercury Project - Removal of Barriers to the Introduction of Cleaner Artisanal Gold Mining and Extraction Technologies.

In order to identify sites with high concentration of mercury (hotspots) a sampling campaign of soils, sediments and biota was conducted, consisting of 768 samples split into 420 biological indicators as fish, plants and shells, and 348 inorganic indicators as sediments, soils and water. The present report describes characteristics of environmental samples and results of mercury analyses in samples from Indonesian gold mining areas in Talawaan (North Sulawesi) and Galangan (Central Kalimantan). An attempt to describe the distribution of mercury and to achieve an environmental assessment of mercury pollution is presented. A research team comprizing 11 scientists from CETEM (7 members) and IFM (4 members) proceeded to Indonesia in September 2003 and has accomplished the sampling campaign within 35 days.

The Health Assessment project is part of a major UNIDO project to remove "Barriers to the Introduction of Cleaner Artisanal Gold Mining and Extraction Technologies", which is performed in six countries. The main funding comes from GEF through UNDP to UNIDO. The University of Munich is subcontractor to CETEM for the health assessment in Indonesia.

The aim of the subcontract was to undertake two medical investigations of approximately 250 people living in the Karang Pangi area (Kalimantan), and of approximately 250 people living in the Tatelu area (Sulawesi), both in Indonesia. The ultimate aim of the whole UNIDO project is to reduce mercury losses in the project demonstration sites by means of introducing new technologies, while improving the income of the miners through more efficient recovery, increasing knowledge and awareness, and providing policy advice on the regulation of artisanal gold mining with due consideration for gender issues.

Over 100 years ago, the Dutch complained of artisanal gold mining in the nearby Ratatotok region in the North Sulawesi, and illegal miners still operate in that region. In 1997, the awarding of a gold mine concession to the Aurora Mining Co. of Australia in the Dimembe Sub-district in the North Sulawesi Province, northeast of Manado City, gave rise to a gold rush of artisanal miners to the area and this rush has expanded to include thousands of miners (Limbong et al., 2003). According to this author, fluctuation of Hg levels in water and sediment in relation to the sampling sites and gold processing plant locations within the Talawaan Watershed provide insight into the pathway of Hg dispersion from gold processing plants throughout the river system. Increasing Hg levels in fish samples provided strong indication of a high bioaccumulation within this contaminated area.

Mercury

Mercury is a silvery-white shiny heavy metal, liquid at room temperature. Mercury exists in different forms:

- Metallic (elemental) mercury (Hg^0)
- Liquid in room temperature (less toxic), as mercury vapor highly toxic
- Inorganic mercury (salt of Hg^{2+})

The lungs absorb 80% of mercury vapour. Target organs are the brain (cerebellum) and the kidney. Mercury is a neurotoxin, nephrotoxin and teratogen. Mercury can cause acute and chronic intoxication.

Chronology of the Field Work in Indonesia

August 2nd 2003 (Munich – Jacarta) – IFM´s staff proceeded to Jacarta;

August 4th 2003 (Jacarta – Palankaraya/Kalimantan) – IFM´s staff proceeded to Palenkaraya, and on the next day to the Central Kalimantan mining area;

August 15th 2003 (Palenkaraya – Manado) – IFM´s staff transfer to Manado;

August 17th 2003 (Manado – Talawaan) – IFM´s staff proceeded to the Talawaan area;

August 29th 2003 (Talawaan – Manado) – IFM´s staff transfer to Manado;

August 30th 2003 (Rio de Janeiro – Jacarta) – CETEM´s staff proceeded to Jacarta, and one day later to Manado;

September 1st 2003 – IFM´s and CETEM´s staff meeting with Indonesian Projects´s counterparts in Manado for Field Work Briefing;

September 2nd 2003 (Manado – Talawaan) – CETEM´s staff proceeded to the Talawaan area; IFM´s staff proceeded back to the office;

September 12th 2003 (Talawaan – Manado) – CETEM´s staff transfer to Manado;

September 13th 2003 (Manado – Palenkaraya) – CETEM´s staff transfer to Palankaraya, and one day later to the Central Kalimantan mining area;

September 25th 2003 (Palenkaraya – Jacarta – Rio de Janeiro) – CETEM´s staff proceeded to Jacarta, and one day later back to the office for laboratory work and Field Work Report.

1.1. Location of the Study Areas in Indonesia

A large number of artisanal gold mining workers in Indonesia indicates that this activity has great importance as an informal employment opportunity in rural areas. However all related processes of separating gold ores using mercury are undertaken with a low level of technical knowledge and skills, no regulation, and with disregard for the safety of human health and environment. The situation is generating serious potential health and environmental risks. According to official estimates of Department of Energy and Mineral Resources, there were more than 500 locations where some 100,000 illegal small-scale gold miners were active in 2000, whereas more than 500,000 people depend on this activity for their livelihood (Aspinall, 2001). Artisanal and small scale gold mining covers West and Central Java, Sumatra, Central and East Kalimantan, North Sulawesi and others, while nearly 180 tonnes of mercury are released to the environment annually (UNIDO, 2002).

1.1.1. North Sulawesi - Talawaan

North Sulawesi is a region in the Celebes Sea. Manado is the capital of North Sulawesi, and has approx. 600.000 inhabitants.

Manado is beautifully situated directly at the sea, and Manado Bay is surrounded by some famous islands, for example Bunaken island. Bunaken National Marine park is well known for its beautiful coral reefs, which are a tourist attraction. Three small rivers drain into this bay. They origin from the Talawaan watershed, approx. 20 to 30 km away from Manado. These rivers come from the Klabat mountain in the mining area of Tatelu. The countryside is very hilly, and dominated by palm trees, and intensive farming. Gold fish is cultivated in fish ponds in the Talawaan area.

Tatelu is a small village with approx. 2.000 inhabitants. Next to the village is the mining area. The ore is mined up in the mountains. A group of 15-20 miners live in very basic camps beside their tunnel.

The tunnels have a small diameter, just enough that one person can fit in, and are dug by hand. Tunnels are not very deep, approx. 20-35 meters. The miners try to follow veins, so tunnels are curved, and tend to be very steep. Miners work in shifts.

Although mainly young men work and live here, some women and a few children also live near the tunnels. The ore is carried out in sacks, and the sacks are brought downhill (approx. 30 minutes away) with the support of buffalo carts.

The processing area is still dominated by men, but many women and quite a few children live here too. Numbers of active miners in the mountain and in the valley seem to vary, most estimations were close to 2.000 active miners.

In the Talawaan region, located at the Northern part of Sulawesi Island, the main mining area (N 001° 31′ 51,2″ – E 124° 58′ 53,2″) lies in the Dimembe sub-district, between the villages of Talawaan and Tatelu besides a small creek, draining into Talawaan River and supplying water for small scale gold mining (SSM) activities.

The Talawaan watershed drains from the peak of Mount Klabat (the highest point with 1.995 m), into the western coast of Kabupaten Minahasa and Kota Manado. Mining activity is extended throughout an area of 34.400 ha.

The study area includes the drainage basins of the Talawaan and Tatelu River. The drainages flow through the main gold processing units where mercury is widely used and released. About one third of the coastline of the area is within the boundary of the Bunaken National Marine Park. The coastal environment includes mangrove areas and coral reefs.

Over 100 years ago, there were artisanal gold mining activities in the nearby Ratatotok region in North Sulawesi, whereas illegal miners still operate in that region. In 1997, the awarding of a gold mine concession to the Aurora Mining Co. of Australia in the Dimembe Sub-district in the North Sulawesi Province, northeast of Manado City, gave rise to a gold rush of artisanal miners to the area and this rush has expanded to encompass thousands of miners (Limbong et al., 2003).

The distance from the peak of Mount Klabat to the sea is approximately 20 km. Talawaan and Bailang Rivers flow through the main center of the mining area (Figure 1). Land use in the Talawaan Watershed is primarily agricultural and is dominated by plantations of coconut, clove, and nutmeg. There are also associated areas of irrigated rice cultivation and fishponds. Cattle, pigs, goats, chickens and ducks are reared in the region.

There is no important industry located along the banks of the main rivers (Martens, 2000). Fishing is carried out in the coastal areas, and crabs and molluscs are also collected in the area for human consumption. There are also small aquaculture activities around brackish water in the area.

The population of the area is estimated to reach approximately 150,000 inhabitants (Martens, 2000). The majority of households in the area are dependent upon agriculture as their main source of income and sustenance, but the number of individuals involved in gold mining has increased rapidly since 1998.

The mining areas are located in the villages of Tatelu, Warukapas, Rondor, and Talawaan of the Dimembe sub-district. By June 2001, there were approximately 400 gold processing plants in the entire area, while nowadays it is estimated a number of 130 units in the Tatelu area alone. The processing plants are mostly built close to river margins. Processing plants are primarily located in the upper part of the watershed. This mining area is more accessible than other mining areas in the North Sulawesi Province, since it is located in an agricultural area near the villages, and is also close to Manado, the capital of the province.

According to results obtained by Limbong et al. (2003) the fluctuation of Hg levels in water and sediments in relation to the sampling sites and gold processing plant locations within the Talawaan Watershed provide insight into the pathway of Hg dispersion from gold processing plants throughout the river system. Increasing Hg levels in fish samples provided strong indication of a high bioaccumulation within the area. According to the authors, environmental contamination due to Hg from artisanal gold mining activities is elevated. Therefore, reduction of Hg emission from the processing plants should be of immediate concern. A regular monitoring program would be necessary in order to better elucidate the rate of bioaccumulation and biomagnification. Such a program would also facilitate a more detailed risk assessment regarding human health issues.

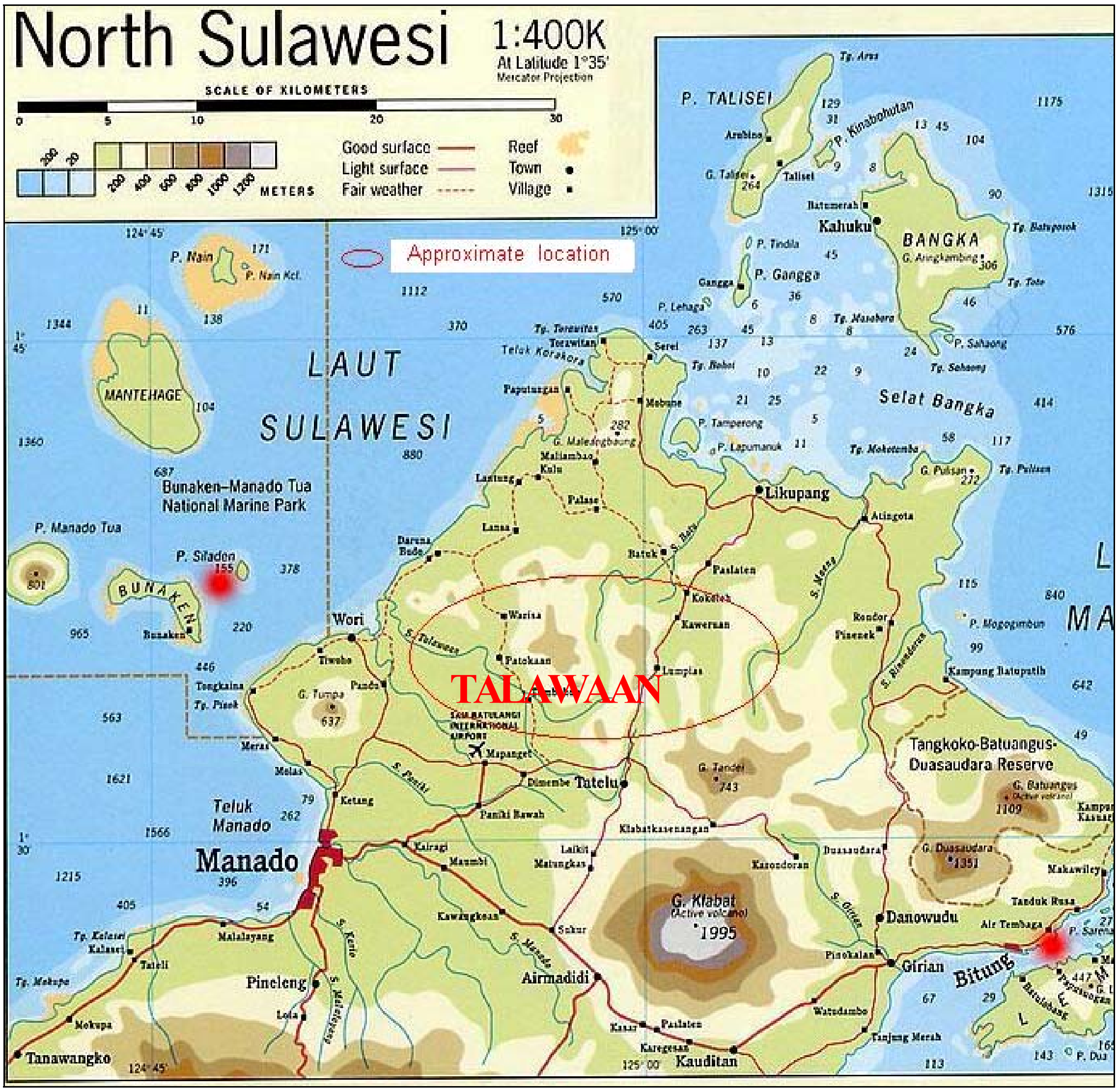


Figure 1 - Approximate location of the Talawaan Watershed. Source: perso.wanadoo.fr/pnoel/ map_sula.htm

1.1.2. Central Kalimantan - Galangan

Katingan District, located in the southern-central part of the Island of Kalimantan, also known as Borneo Island, the main mining site is Galangan (001° 59′ 16,4″ S – 113° 17′ 09,1″ E), also known as Ampalit, lying on the right margin of the Katingan river which drains into the Java Sea about 200 km to the South (Figure 2).

Galangan mining site is located just 7 km away from Kereng Pangi village, district of Katingan, which provides infrastructure for miners in Galangan.. This region can be reached by automobile, taking 90 minutes from Palangkaraya (the capital city of Central Kalimantan Province). The geographic coordinates of this region are from 01°56,563′ S to 02°00,349′ S and 113°16,565′ E to 113°17,182′ E.

In Central Kalimantan from Palangkaraya airport it takes approximately 40 minutes by car to Tangkiling (control area), and another 30 minutes to Kasongan (District capital). Another 20 minutes further to the west is located the village of Kereng Pangi (mining town).

The climate is wet tropical with mean daily temperatur of 32 °C and two main seasons, a dry season helding from May to September and a rainy season from October to April. The approximate precipitation in the rainy season reachs 271-418 mm, whereas in the dry season these values decrease to 33-179 mm.

The earliest incidence of small scale mining activity in Central Kalimantan has begun at Tewah-north of Palangkaraya, upstream of Kahayan River, in 1987. Illegal miners worked at several places in the area belonging to the mining company PT. Tambang Tewah Perkasa. The places known as Gudang Setengah, Sumurmas, and Batu api were target, whereas the Sumurmas village formed due to the mining activity. The Indonesian Government has undertaken various programs and implemented law enforcement to regulate their activity. Nevertheless, from these locations illegal mining spread all over Central Kalimantan, one of them known as Galangan (J. Dwipriambodo Report, 2003).

Galangan is on the eastside of the Contract Work Area of PT. Ampalit Mas Perdana (Gold Mining Company) that recently stopped its activities in the area.

The small scale gold mining activity has begun in this area in 1998, while at the end of 1999 there were at least 437 processing units. In the middle of year 2000 more miners came and so this number increased to more than 500 units (according to the monitoring data of August 2000, Mines and Energy Office of Central Kalimantan). Since each unit is operated by 4-6 worker, so there are at least 2,500 workers directly involved in the mining activity in this area.

Most miners came to Galangan from outside this island, most of them from Java, South Kalimantan and Madura, before ethnical conflict of 2001, when hundreds of miners were killed, being the remaining miners from

Madura expeled. The causes of this gold rush in Galangan can be described as a combination of the following factors:

- impact of the Indonesian economic crisis in the middle of 1997 that caused significant unemployment;
- Easy accessibility;
- Relatively simple technology and low capital cost.

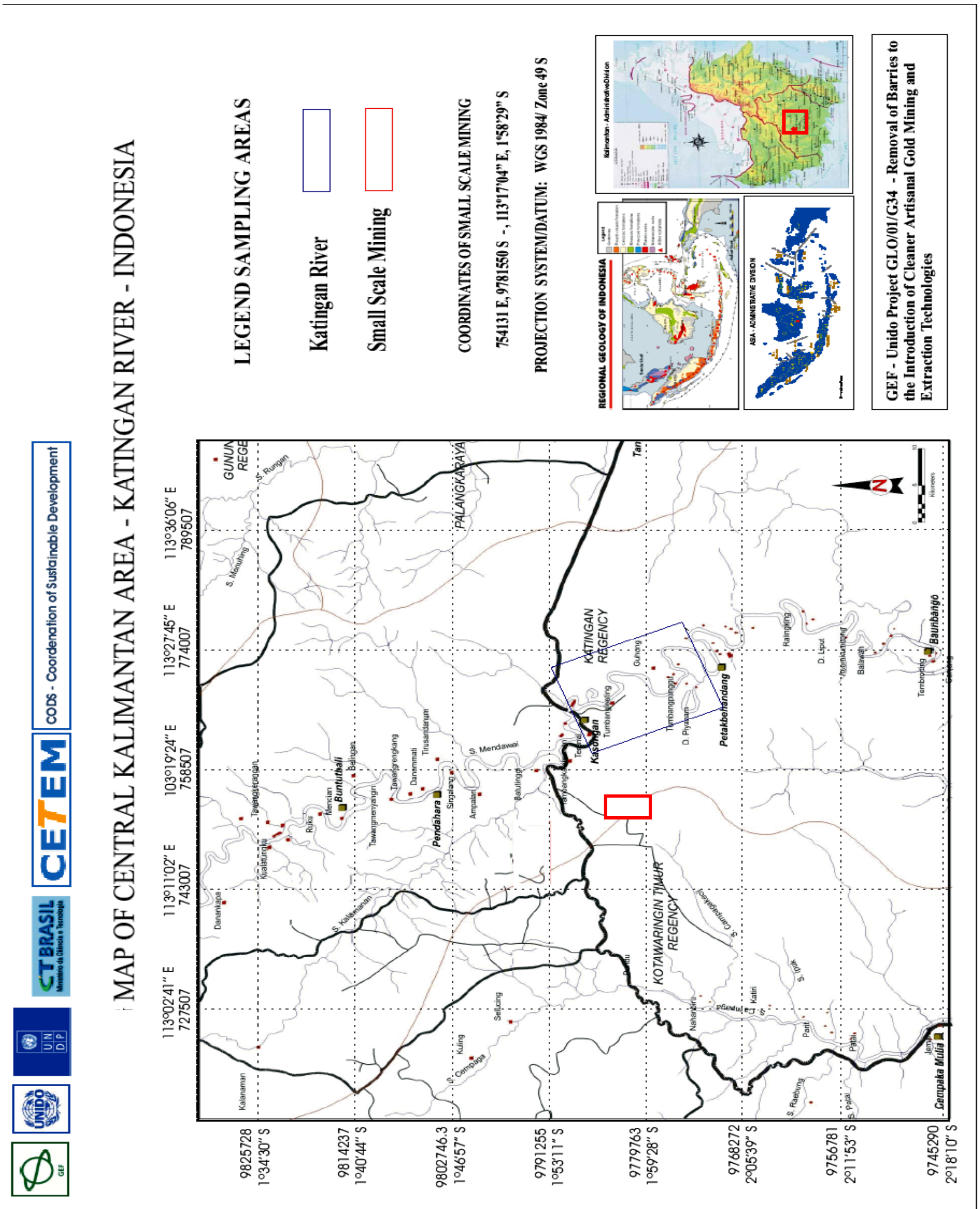


Figure 2 - Map of study areas in the Galangan Mining site (Central Kalimantan)

2. Materials and Methods

2.1. Environmental Assessment

2.1.1. Sampling estrategy

A sampling campaign of soils, sediments and biota was conducted, consisting of 768 samples split into 420 biological indicators as fish, plants and shells, and 348 inorganic indicators, as sediments, soils and water in order to address both the identification and evaluation of mercury hotspots. Amalgamation tailings dumped into drainage systems originate hotspots of metallic mercury (*mining hotspot*), where abnormally high concentrations are to be found in the heavy fraction of sediments.

Due to its typical heterogeneous distribution, one may face enormous difficulties in locating a mining hotspot of mercury and its dispersion patterns downstream in a given mining area, as conventional geochemical exploration techniques have been used unsuccessfully in previous studies. Therefore, the introduction of novel sampling and analytical methods has been required, including *in situ* mercury analyses by either a semi-quantitative colorimetric method or a quantitative field analyser.

Individual and composite substrate (soil and sediment) samples were collected with an plastic shovel, labeled, and stored in plastic bags. Composite samples were obtained mixing sub-samples in the plastic bags.

Sampling and analysis of total suspended solids (TSS) and water in aquatic systems play a pivotal role in assessing mercury mobility and the nature of pollution. Mercury transported either in solution or onto suspended particles may be deposited in riverside deposits forming mercury sinks, which are potential sources for mercury remobilization, since mercury is adsorbed onto fine particles and prone to form soluble complexes, mainly in the presence of humic substances. Therefore, high contents of organic matter in sediments have been sought during sampling.

Simple sampling methods, consisting of pan concentrates for mercury analysis were also used for locating mercury hotspots. Another approach enables the reconstruction of the local mining history and the identification of amalgamation tailings, through establishing confidence among miners and researchers, so that they agree to indicate places where former activities have been conducted.

Some physiochemical parameters are considered important for assessing the mobility of mercury in the environment, and its eventual bioaccumulation and/or biomagnification in fish, mainly as methilmercury. Therefore, physiochemical parameters of water, such as temperature, electrical conductivity, pH and dissolved oxygen were determined in the drainage waters by multi-electrodes.

Since sampling of TSS by filtering through 0.45 μm membranes has been reported in some cases as controvertial, due to its unefficiency of recovering enough solid material for analysis, it was sought naturally settled TSS samples where favorable hydrodynamic conditions were to be found.

Fish samples were collected by gill-netting and fishing line with a fish-hook. Each specimen was weighed (Wt), and its length (Lt) was measured at the time of collection.

Plant samples were collected manually or using a shovel to dig out the roots, washed several times, labeled, stored in plastic bags and frozen. Approximately three replicates of each specimen were collected. In laboratory, plants samples were washed with tap water and cleaned with a small brush to remove potential aerial superficial mercury contamination. Roots, stems and leaves were analyzed separately. Wet materials were used to obtain total mercury concentrations in plant parts. Water contents in plant samples were utilized to transform wet weight concentration to dry weight concentration.

2.1.2. Sample Preparation and Analyses

Preparation of sediment, soil and tailing samples consisted of homogenization followed by wet sieving for separating grain size fractions above and below 200 # (74 μm). After that, each fraction has been dried at 40 °C for analysis.

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

The method used in the laboratory for the determination of total mercury in environmental samples (soils, sediments, fish) follows the methodology developed by Akagi and Nishimura (1991). It involves acid digestion followed by reduction to elemental mercury, aeration and measurement of mercury absorption with cold vapor atomic absorption spectrometry.

The sample digestion procedure insures complete digestion of organic materials and at the same time avoiding mercury loss by using a combination of acids and oxidizing agents. This combination involves a mixture of nitric, perchloric and sulfuric acids. Additionally, water is added to protein-rich samples, to avoid frothing upon heating. The sample is then heated at 250oC for 20 minutes. The sample solution is reduced by staneous chloride, generating elemental mercury vapor, which is then circulated in a closed system. Absorbance is measured when equilibrium of mercury vapor between gas and liquid phases is reached. The use of a syringe with needle when adding the reducing agent avoids loss of mercury by vaporization. The detection limit of the method is 0.5 ng Hg.

Hg was analyzed in the fish muscle through Atomic Absorption Spectrophotometer (KK.Sanso SS) using a Vapor Generation Accessory-VGA (CVAAS). For the analysis of Hg-total, approximately 0.5 g of tissue was weighed in 50-ml-vol flasks, to which was added 2 ml of HNO_3-$HClO_4$ (1:1), 5 ml of H_2SO_4, and 1 ml of H_2O (Hg free), and heated on a hot plate to 230-250°C for 20 minutes. After cooling, the digested sample solution was made up to 50 ml with water. An aliquot (5 ml) of digested sample solution was introduced in the Automatic Mercury Analyzer Hg 3500. The difference in duplicate sample analyses was less than 10% (precision of measurements was 90%). The accuracy of analyses was estimated with analyses of biological tissue standard reference materials from International Atomic Energy Agency. The results indicated that sample preparation and analytical procedures consistently produced accurate measures of Hg concentrations.

2.1.3. Statistical Analyses

Statistical significance between Hg concentrations and allometric parameters (weight and length) among fish from different SSM sites were tested using parametric Student's T-test after Levene's test for equality of variance, or, if the underlying assumptions for parametric testing are not met, a nonparametric test of significance, the Mann-Whitney U-test was employed. The significant level considered was the probability level ≤ 0.05. Correlation analyses were determined with both the Pearson correlation coefficient and/or the Spearman rank correlation coefficient. Significance of the correlation was determined with a two-tailed Student's *t* test. One-way ANOVA followed by Duncan pos-hoc were performed when appropriate for testing differences among groups.

Quality assurance/quality control (QA/QC) concerns were addressed through the use of analytical duplicates. Analytical duplicates were included with each sample, and duplicate analyses for each sample were checked to assure that the relative percent difference between duplicates was no greater than 10%.

2.2. Health Assessment

2.2.1. Material and sample storage

From 492 participants in Indonesia 491 blood samples, 492 urine samples and 488 hair samples were taken. The blood samples were taken in EDTA-coated vials. The urine samples were acidified with acetic acid. To avoid degradation, all blood and urine samples were stored permanently and transported by flight to Germany in an electric cooling box. Until analysis these samples were stored continuously at 4 °C.

2.2.2. Study Setting and Clinical Examinations

The "Protocols for Environmental and Health Assessment of Mercury Released by Artisanal and Small-Scale Gold Miners" were developed by

UNIDO in collaboration with the Institute of Forensic Medicine, LMU of Munich, and other international experts (Veiga 2003).

The declaration to volunteer was translated in Bahasa Indonesia as well as the "Health Assessment Questionnaire" (Appendix 2). The questionnaire was used to examine the general health condition of members of the mining communities and to indicate symptoms of mercury poisoning. Anamnestic / clinical / neurological / toxicological tests were used according to the state of the art. Participants were examined to identify neurological disturbances, behavioural disorders, motor neurological functions, cognitive capabilities, balance, gait, reflexes etc.. The data was compiled for statistical purposes and maintain confidentiality regarding all health related issues. All participants were physically examined including neurological testing.

2.2.3. Health Project in the Field

The health project in the field took place from the 2nd of August 2003 until the 8th of September 2003. In Kalimantan the equipment was set up in the health centre of Kereng Pangi, in Sulawesi in the village hall of Tatelu. Both facilities were sufficient to perform the examinations, including a mobile analysis of Hg in urine samples (examination rooms for the team, electricity, toilet, water).

Team members for the health project in the field were Dr. med. Stephan Boese-O´Reilly (paediatrician, master of public health, environmental medicine), Stefan Maydl (physician), Alexandra Dittmann (pharmacist) and Sven Illig (Physician). Mrs. Selinawati was the Assistant Country Focal Point to UNIDO and comes from the Indonesian Ministry of Energy and Mineral Resources. Assigned to the project were nurses to assist the medical examinations, Asnedi, Muhlis Afatzli, Lesi, Gunarti, Emilia and Susanti in Kalimantan including Dr. Robertus Pamuryanto; and in Sulawesi J. Palit, Perumahan Banua Buha Asri and Mrs. Marly Gumalag. These nurses interviewed all participants.

A mobile Hg analyser was used to determine total mercury in urine.

Video and photo documentation was carried out.

The control group for Kereng Pangi / Kalimantan was examined in Tangkiling. The control group for Tatelu / Sulawesi was examined in Air Mandidi. The same methods and teams as in the gold-mining areas were used. The local health unit in Tangkiling supported the examination. Tangkiling is approx 35 km away from the mining area, and mercury is not used in the village. In Air Mandidi the local school and drinking water company supported the examination. Air Mandidi is approx. 30 km away from the mining area, and mercury is not used in the area.

Blood, urine and hair were analysed for mercury later at the Ludwig-Maximilians-University of Munich, Germany.

2.2.4. Questionnaire

The participants filled in a questionnaire with assistance from the nurses.

Questions included:

Working with mercury or with mercury polluted tailings?

Burning amalgam in the open?

Melting gold in the open or with inadequate fume hoods?

Drinking alcohol?

Having a kind of a metallic taste?

Suffering from excessive salivation?

Problems with tremor / shaking at work?

Sleeping problems?

Neurological examination

All participants were clinically, mainly neurologically examined. Results were mainly primarily scored according to „Skalen und Scores in der Neurologie“ (Masur 1995):

Signs of bluish discoloration of gums

Rigidity, ataxia and tremor

Test of alternating movements or test for dysdiadochokinesia

Test of the field of vision

Reflexes: knee jerk reflex and biceps reflex

Pathological reflexes: Babinski reflex and mento-labial reflex

Sensory examination

Neuro-psychological testing

The following tests were carried out (Zimmer 1984, Lockowandt 1995, Masur 1996):

Memory disturbances: Digit span test (Part of Wechsler Memory Scale) to test the short term memory

Match Box Test (from MOT) to test co-ordination, intentional tremor and concentration

Frostig Score (subtest Ia 1-9) to test tremor and visual-motoric capacities

Pencil Tapping Test (from MOT) to test intentional tremor and co-ordination

Visual field test

The visual field was measured in a very simple way without the need of any electricity. It was added to the health assessment protocol.

Tremor-meter

A new approach to measure tremor in a more objective way was performed. PD Dr. Boetzel from the Neurological Clinic, University Hospital in Munich supplied the team with an instrument to measure tremor. This instrument is still at a developmental stage. A small sensor was placed on the fingertip (right and then left side) of each participant. A special electronic unit, developed by the University, measured the signal and the digital signals were recorded onto a laptop.

Three different measurements were performed:

Arms outstretched – for intentional tremor

Arms bend with the finger tip pointing to the nose – for intentional tremor

Arms outstretched - moving fast for 30 cm from left to right and back – for movement analysis.

Due to a few technical problems not all participants could be tested. There are no results yet available.

The second objective way, the video tapping of finger tremor still needs to be evaluated, but was good to perform.

Specimens

The following specimens were taken, and two tests (Hg in urine and proteinuria) were performed immediately:

Blood (EDTA-blood 10 ml)

Urine (spontaneous urine sample 10 ml)

Hair

If a woman was breastfeeding, she was asked for a breast milk sample (to analyse for mercury).

The specimens urine, blood and breast milk were cooled permanently after collection until arrival in the laboratory in Munich, Germany.

Laboratory

A mobile Hg analyser was used (Hg-254 NE, Seefelder Messtechnik, Seefeld, Germany). It is possible to quantify inorganic mercury in urine. 1 ml urine was diluted with 100 ml water (bottled drinking water). A 2 ml solution of 10% tin(II)chloride in 6N hydrochloric acid was added to the water-urine solution. The sample was analysed by atomic emission spectrometry. Bottled drinking water was used as zero standard, and a mercuric nitrate solution as standard. In most cases it was possible to analyse the sample. One urine sample can be analysed in approximately 3 minutes. All urine samples were re-analysed in the "Institute of Forensic Medicine", Munich, Germany.

Test for protein in urine

Protein in urine was tested with a commercial kit (Teco diagnostics URS10). The test is based on the error-of-indicator principle. Test reagents are 0,3 % w/w tetrabromophenol blue; 99,7 % w/w buffer and non-reactive ingredients. At a constant pH, the development of any green colour is due to the presence of protein. Colours range from yellow for "Negative" reaction to yellow-green and blue-green for a "Positive" reaction. The test area is more sensitive to albumin than to globulin, haemoglobin, Bence-Jones proteins and muco-protein. The test area is sensitive to 15 mg/dl albumin. The test strip was dipped into the native urine and the result was taken after 1-2 minutes. The test is semi-quantitative. Possible results are 0, trace, 30, 100 and 300 mg Protein / dl urine.

Sample preparation

Hair: 20 mg – 200 mg (if available) hair was cut in small pieces and weight exactly. All mercury was extracted from the hair samples by shaking with 10 ml hydrochloric acid 6 N for 15h at room temperature in the dark. Parts of the elute were analysed by CV-AAS with two different reduction agents (see below).

Intentionally washing steps with water, detergents or organic solvents like acetone were not performed before the elution. Washing procedures with different solvents are frequently applied before hair analyses with the aim to remove air-borne heavy metal pollution from the surface of the hair. But as shown in literature, a distinct differentiation between air-borne and interior mercury cannot be achieved which such washing procedures (Kijewski 1993). Orientating pre-experiments with washing hair samples from burdened groups supported this assumption. After washing some samples from the same strain, the results were not reproducible. Therefore the hair samples were eluted without any further pre-treatment.

Blood, urine: Aliquots of up to 1.0 ml were analysed directly without further pre-treatment (method see below).

Mercury determination and quality control

The total amount of mercury in the samples (blood, urine, elute from hair) was determined by means of so-called cold-vapour atomic absorption spectrometry (CV-AAS), using a Perkin-Elmer 1100 B spectrometer with a MHS 20 and an amalgamation unit, Perkin-Elmer, Germany. Sodium-borohydride

($NaBH_4$) was applied for the reduction of all mercury (inorganic and organic bound). $NaBH_4$ reduces inorganic mercury quicker than organic bound mercury like methyl-mercury. Nevertheless it is possible with this method, to determine the correct amount of total mercury, because all nascent mercury vapour is inter-collected on a gold-platinum-net. In a second step the net is heated and all trapped metallic mercury is released at once and could be quantified by CV-AAS. The accuracy of the method for inorganic as well as organic mercury compounds was proved by inorganic and methyl-mercury standard solutions. The determination limit for total Hg in blood or urine was 0.20 µg/l, for total Hg in hair 0.02 µg/g (calculated for a 100 mg hair sample).

In addition, in the elutes of the hair samples, the amount of inorganic mercury was determined by CV-AAS, using a Lumex Zeeman mercury analyser RA-915+, Lumex Ltd., St. Petersburg, Russia. This equipment operates with $SnCl_2$ (tin-II-chloride) for reduction. With this method, only inorganic mercury can be detected, because under acid conditions $SnCl_2$ reduces only inorganic mercury and not organic bound mercury like methyl-mercury. This was proven by inorganic mercury standards (which show a signal) and methyl-mercury standards (which show no signal at all). The determination limit for inorganic Hg in hair is 0.04 µg/g (calculated for 100 mg hair).

All analyses were performed under strict internal and external quality control. The following standard reference materials served as matrix-matched control samples: human hair powder GBW No. 7601 (certified Hg 0.36 ± 0.05 µg/g) and Seronorm whole blood No. 201605 (certified Hg 6.8 – 8.5 µg/l). Since many years the lab participates successfully in external quality control tests for mercury in human specimen.

Statistical methods

Statistics were calculated by means of the SPSS 9.0 programme (SPSS-software, Munich, Germany). As expected, the mercury concentrations in the bio-monitors (blood, urine, hair) were not distributed normally but left-shifted. Therefore in addition to the arithmetic mean (only for comparison to other studies) the median (50% percentile) is given. For all statistical calculations distribution-free methods like the Mann-Whitney-U-test for comparing two independent groups, the Kruskal-Wallis-test for comparing n independent groups, the Chi-square test for cross-tables or the Spearman rank test for correlation were used. “Statistically significant” means an error probability below 5% ($p < 0.05$).

Some graphs were shows as so-called “box-plots”. For a brief explanation: The “box” represents the inter-quartile (this means from the 25% to the 75% percentile). The strong line in the box is the median (50% percentile). The “whiskers” show the span. Outliners are indicated by dots.

3. Results and Discussion

3.1. Environmental Assessment

3.1.1. Geology and Mineral Processing in North Sulawesi (Talawaan)

According to Turner (2002), the North Arm of Sulawesi is a classic oceanic island arc that includes porphyry Cu and volcanic-hosted epithermal Au-Ag deposits. The Ratatotok Au district, located 100 km to the Southwest of Manado, is hosted in Miocene carbonate rocks deposited in a Northeastern-trending graben, and covered by andesitic volcanic and volcaniclastic rocks. Carbonates are silicified, decalcified, dolomitized, and have anomalous concentrations of Hg, As, Sb, Tl and low base-metals, as Zn, Cu and Pb (all < 100 ppm). Acessory minerals include cinnabar (Hg sulphide). As for the gold deposit in Talawaan, a similar mineral and chemical composition is likely to occur, due to geological and structural features of this gold deposit. Therefore, one may realize that a naturally anomalous Hg background is to be found in North Sulawesi.

In Talawaan, primary ore deposits are mined in a hilly area (Figure 3) located 1 km from the processing site, through mostly vertical shafts and tunnels - some of them up to 17 m deep and very narrow (Figure 4) Miners are operating for 6 years and extract from 0.5 to 1 tonne/day of partially weathered ore. The material is crushed to –1/2" by stomp mills to be delivered to the milling units.

Figure 3 - The hilly mining site in Talawaan (Tatelu)

Figure 4 - Young miners and entrance of a shaft in Talawaan (Tatelu)

The ore, after filled in sacks and pulled up through a rope elevator, manually operated, is transported on simple wooden sleighs, draged by cows or oxes to the processing site. There, the ore is spread and dried in the sun, before it is crushed manually or by stomp mills, in order to reduce the processing time in the ball mills. Then the crushed ore is fed into ball mills for simultaneous grinding and amalgamation. Some 30 – 40 kg of ore are loaded into steel-made cylinders (a type of ball mill, called „trommel") together with hard stones (river pebbles), some water and about 1 kg of mercury (Figure 5).

Figure 5 - Pouring mercury into the ball mill

It was estimated 130 milling operations in the Talawaan watershed (Tatelu region) and found out that mill operators have purchased from 10 to 15 kg of mercury/month/milling unit. A unit with 12 mills recovers 4 to 6 g of gold per cycle. Generally there are two cycles per day. The mills operate 8 hours/day, 6 days/week. The price of mercury sold by the material suppliers in Tatelu is US$ 9/kg.

Each of those processing plants operates 10 to 12 "trommels" in an integrated system (Figure 6). The "trommels" – diameter of 50 cm and lenght of 80 cm - are driven by an internal combustion engine via belts and rotate for 3 to 4 hours. Each steel mill, with diameter of 48 cm and length of 50 cm and has capacity of milling 40 kg of ore per batch. Then the grinding step is interrupted and about 1 kg of mercury per mill is added and the mill rotates for an additional hour. The ground product becomes finer than 200 mesh (0.047 mm).

The grinded and amalgamated ore is poured out of the "trommels" with water into bowls for settling down the heavy metal alloy (mercury and gold-amalgam) in the bottom (Figure 7). Water is added again to remove the light fraction, leaving the amalgamated gold. Mercury amalgam is separated from the ore by panning ins a plastic bowl followed by manual squeezing in a piece of fabric. No proper panning is employed in this operation, so that huge amounts of Hg are expected to being released from those processing sites.

Most miners are currently storing amalgamation tailings in plastic sacks to be sold to cyanidation plants. Since a certain portion of the gold is not recovered from the gold ore by the amalgamation process, the wastes of the processing sites are collected into sacks and transported by cars to nearby located cyanidation plants, where the material is chemically processed to extract the gold left in the amalgamation wastes.

Figure 6 - A typical processing unit with a set of ball mills ("trommels")

Figure 7 - Recovery of Hg-Au amalgam by rough "panning"

A possible explanation for this carelessness in dealing with amalgam recovery is related to a subsequent chemical treatment of amalgamation tailings in cyanidation tanks, which recovers the Au lost during amalgamation, and partially Hg.

The resulting amalgam is usually burned in open air (Figure 8). No retorts are used in this operation, being the only tentative protection to the operator the covering of mouth and nose with a part of the shirt or, rarely, with a mask for dust filtering. For the roasting process, borax is added to reduce the melting point of gold and to remove impurities from the final product.

Figure 8 - Amalgam Hg-Au and its burning in open air

Mercury Loss

The estimated ratio Hg_{lost} : $Au_{produced}$ falls in the extremely high range of 40 to 60, which is 30 to 40 times higher than average ratios found in SSM worldwide.

Assuming that 9.6 to 14.4 kg of Hg are lost per unit/month, not less than 15 to 22 tonnes of mercury are being released annually in the entire area of Tatelu. This characterizes an alarming mercury burden to the environment in North Sulawesi.

In Talawaan, a cyanidation unit comprises a cylindrical vertical tank, containing a volume of about 20 to 30 m^3 (Figure 9). The owner of the visited cyanidation unit pays Rp 3500 (US$ 0.40) per sack of 40 kg of amalgamation tailings. To leach 20 tonnes of material 100 to 200 mg/L NaCN is added at pH 11, adjusted with lime and controlled once a day. The pulp (ca. 40% solids) is agitated, while an air compressor provides the ventilation to the pulp during the leaching process, lasting around 2 days. Approximately 500 g of residual mercury are regained by settling down in each tank per batch. According to average Hg concentrations found in amalgamation wastes, this Hg recovery represents only 10 to 20% of the Hg burden contained in those wastes.

Figure 9 - A cyanidation tank in Talawaan (Tatelu)

Some 100 to 150 kg of activated charcoal are added into the leaching tank. After 3 batches (i. e. ca. 60 tons of processed material) the charcoal is recovered by screening and the tailings are deposited in a large non-lined tailing pond for tentative neutralization. The Au-Hg-loaded activated charcoal is burned in open drums to recover 500 g of gold in average per cycle, whereas Hg is released again to the atmosphere.

Miners indicated that occasionally sodium hypochlorite is added to destroy residual cyanide, but they count with natural cyanide degradation (sunshine) to do the work. Operators do not have knowledge on elution processes to extract gold from the loaded activated charcoal.

It is clear that the sedimentation tank collects a small part of the residual mercury from the amalgamation tailings, while a major amount of mercury is leached in the cyanidation process and part stays with the cyanidation tailings as mercury cyanide complex. The workers are not aware about the mercury vapor exposure when they burn Au-Hg-loaded activated charcoal.

3.2 Geology and Mineral Processing in Central Kalimantan (Galangan)

Due to the topographic flat character of the sedimentary basin, its main rivers, Katingan and Kahayan, exhibit a strong meandering stream, while the local wetland in Galangan flows gently to two different river basins, to the Katingan River to Southeast and to the Cempaga River to Southwest.

A 1 km wide forest remains separating the mining operations from the Katingan River. The mining area consists of a flat plain seasonally flooded, covered by alluvial, Quaternary-Tertiary sediments – mostly sand and gravel with thicknesss ranging from 2 to 10 m above peaty layers. The occurrence of peaty layers is an indication of a former wetland forest, which now lies some meters above the groundwater table. Therefore, it seems to be very plausible, that the main part of the waters from the mining site soaks into its sediments, before it is drained by means of groundwater run off into the adjacent rivers.

The landscape in Galangan resembles a desert, with some isolated trunks and stumps of giant trees after deforestation of the rain forest (Figure 10). No significant vegetation remains and the soil is reduced to a white, fine sand. The alluvial gold ore deposit consists of a Quaternary-Tertiary (Pleistocene) sedimentary sequence.

Figure 10 - Lanscape in the minin site of Galangan (Central Kalimantan)

Mining is carried out following traditional methods also used in the Brazilian gold mining areas (secondary deposits) in the Amazon region. In open pits the gold bearing layers are hosted down by means of hydraulic monitors (Figure 11). The diluted pulp is then pumped to a two-staged carpeted sluices box with an inclination of some 15°, on which gold particles are supposed to settle down in the carpet due to their high density (Figure 12). Due to the high turbulence of the pulp flow a considerable part of the gold is lost to the tailings.

Figue 11 - Hydraulic mining in Galangan

Figure 12 - Sluice Box in action

Mercury is purchased from gold dealers in Kereng Pangi at a price of US$ 10/kg (2.5 times higher that the international market). We could not find out the origin of this mercury. A rough calculation of the miner's operating cost was done through interviews. Mercury represents less than 0.6% of their cost and diesel for the electric 4" pumps represents more than 90%.

Manual amalgamation of the concentrate is done in ponds consisting of flooded open pits excavated beside the miner's residences, being Hg-contaminated tailings left in those ponds. Amalgam is panned following traditional practice in wooden pans, whereas excess mercury is squeezed through a piece of cloth regaining it for further reuse. All families use water from the open pits to take bath and wash clothes (Figure 13).

Figure 13 - Panning of amalgamated Au concentrate into flooded open pits

Mercury Loss

The ratio Hg_{lost} : $Au_{produced}$ in Galangan is estimated in the range of 1.5 to 2. Assuming that 150 to 300 g of mercury are lost per unit/month, 1 to 2 tonnes of mercury are being released annually in the entire area.

Amalgam is burned in gold shops, commercial stores in a chimney-like construction, which leads the mercury vapor just outside the house by an outlet pipe. The gold shops are situated in the middle of the village (Figure 14). There is no proper ventilation for the mercury fumes, where in the rainy season 15 kg of gold is sold to 20 gold shops and melted in the village, releasing at least 200 kg/annum of mercury in the village. Housing areas, food stalls and a school are just nearby.

According to local authorities about 500 processing units exist in the entire mining area, each one with 4 to 6 miners, who work 10 hours a day, during 6 days a week. Some 3 to 8 g of gold are recovered per unit/day.

The ore grade is around 0.3 to 0.5 g/tonne (according to Mr Mansur Geiger, geologist from Kalimantan Surya Kencana). The concentrate of 10 hours of operation is amalgamated in ponds excavated beside the miner's residences. Miners use 100 to 200 mL of mercury (which is around 1 to 2 kg) to amalgamate 5 to 10 kg of concentrate.

Figure 14 - Typical gold shop in Kereng Pangi

3.3. Biogeochemistry of Mercury in North Sulawesi (Talawaan Watershed)

Samples of sediments, soils, tailings, dust, water and bioindicators were taken in the main mining sites as well as along the affected drainage basins in the Talawaan watershed. Remarkably for the whole area is the volcanic nature

of rocks, soils and sediments. Therefore, one may realize that a naturally anomalous Hg background is to be found in the study area, as reported by geological investigations in volcanic-hosted epithermal Au-Ag deposits occurring in nearby areas in North Sulawesi (Turner, 2002).
Nearly no suspended matter is to be found in drainages of the Talawaan watershed due to the „young" nature of the rivers, except in the most downstream region where a plain supplies the rivers with some silt/clay material. Moreover this scarcity of clay minerals might reflect the young age of volcanic activities, since the volcanic rocks have been exposed to weathering for a relatively short geological time.

Also the type of mining process contribute to this sedimentological feature, since relatively small amounts of gold ore are worked and most of the tailings are recovered to be reprocessed in the cyanidations plants, where tailings are confined into ponds. As a result little turbidity could be observed in the creeks and rivers draining the mining region. Larger rivers like Talawaan pours even clear water into the sea.

A sampling campaign of soils, sediments, water and biota was conducted in the Talawaan watershed, consisting of 298 samples split into 156 fish samples, and 142 samples of sediments, soils, water, plants and other aquatic organisms, covering the whole study area (Figure 15) . The sudy area was divided into 7 sub-areas from the most upstream are down to the estuary.

The description of the study sites in the North Sulawesi, Talawaan Watershed, is presented in Table 1.

Table 1 - Study sites in the Talawaan aquatic ecosystems, localization and brief description (D).

	Study Site	Localization	D
T1	Located upstream of the gold mining areas; rice plantation and fish farming activities	01°30'51,2"N 124°58'52,7" E	Spring
T2	It is located about 5 Km downstream of T1, with some gold mining processing units located surrounding. Tatelu river, its tributary flows to Talawaan close this sampling site. The water from the dam is used to rice plantation and fish farming	01°31'50,5"N 124°57'36,0"E	Dam
T3	It is located downstream of cyanidation plants	01°33'10,64"N 124°56'20,1" W	After dam
T4	About 3 km upstream estuarine region		Close estuarine
T5	Estuarine region, high fishing activity		Estuarine region
Control T6	Toldano river, which is located in another watershed. Fish collected in the hydroelectric power plant dam		Dam
Posto T7	Fish market, in Manado city		Manado city

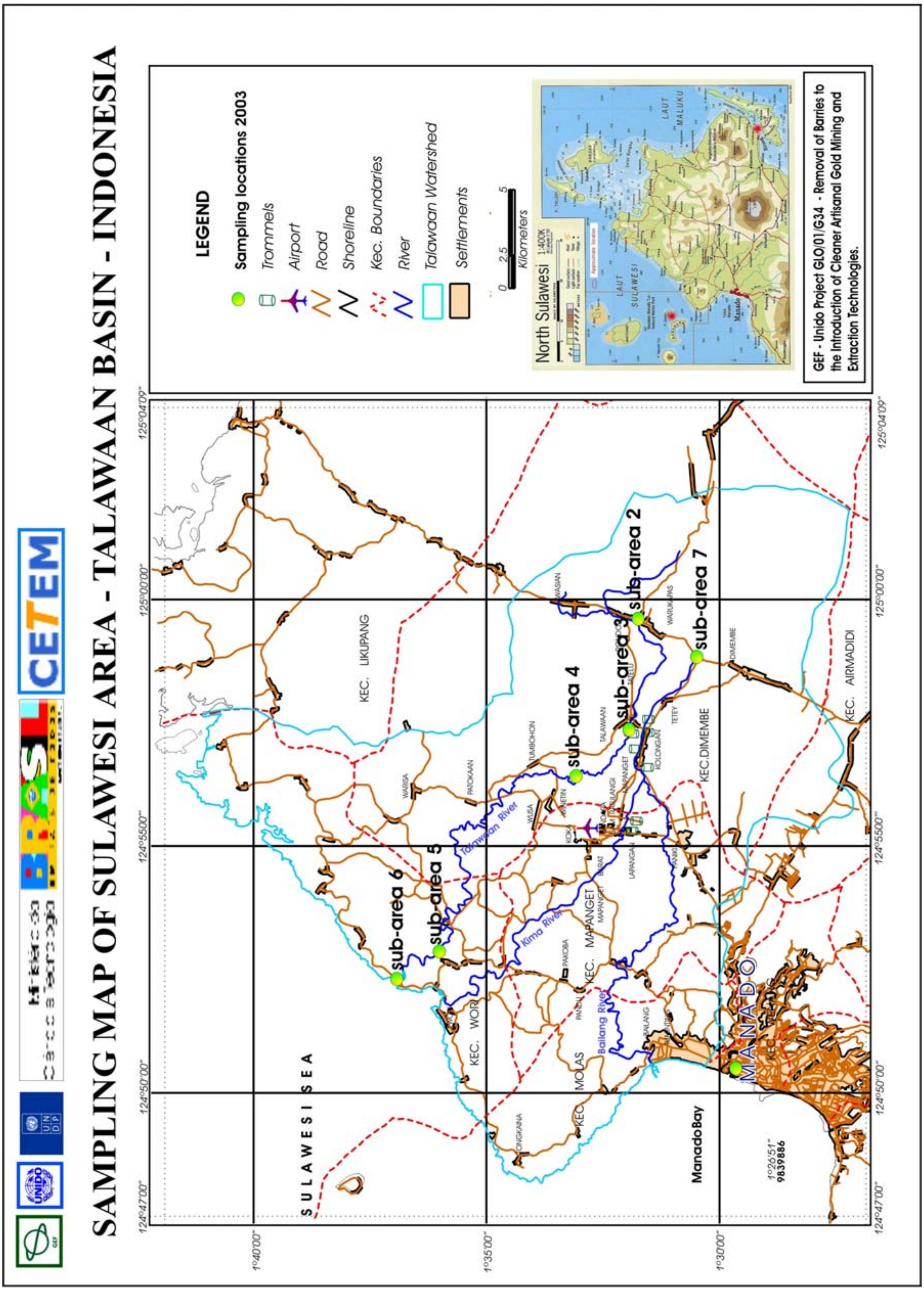


Figure 15 - Location of Biogeochemical Sampling along the Talawaan Watershed

The most uptream sampling site, sub-area T1, is located close to the spring of Talawaan river where no mining activity is to be reported. Therefore, sediment samples from sub-area T1 are believed to mirror Hg levels in sediments unaffected by gold mining activities. Unexpectedly, Hg levels in those samples were 600 times higher than Hg background levels usually found in sediments in tropical regions (Rodrigues-Filho et al., 2004). Mercury levels at the spring of the Talawaan River average 60 μg/g in the sediment fraction < 74 μm (Figure 16).

A likely explanation for this anomalous Hg level in unaffected sediments is related to the proximity of the inactive volcano of Mount Kablat, whose former activity might have generated the conditions for the formation of gold deposits in the Tatelu region, as well as their associated Hg enrichment. This Au-Hg association has been observed in other similar gold deposits in North Sulawesi (Turner, 2002). Another study on mercury contamination of the Talawaan Watershed also indicates abnormal Hg levels, up to 2.0 μg/g, in sediments close to its spring (Martens, 2000), whereas no information on the target grain size fraction has been indicated. However, further investigations on the mineralogy of these sediments are required to confirm this hypothesis.

Approximately 5 km downstream, it is located the main mining sites, sub-area T2, close to the confluence of the Tatelu River and the Talawaan River, where a dam reservoir has been built for water supply to rice plantations. There an increase of Hg levels in sediments has been observed, as a consequence of Hg releases from amalgamation wastes to the rivers. Mercury concentrations reach up to 480 μg/g and average 154 μg/g in the sediment fraction < 74 μm (Figures 16 and 21).

Likewise, mining tailings consisting of amalgamation wastes present Hg levels that characterize a *mining hotspot* with up to 1250 μg/g and an average Hg concentration of 317 μg/g (Figures 17 and 21). Although it was said that amalgamation tailings are forwarded to cyanidation plants, this might not be always the case, since plenty of amalgamation tailings are spread all over the river banks in the sub-area T2. Mercury levels found in tailings of this area are in accordance with the values encountered in mining hotspots of gold mining sites in Brazil (Rodrigues-Filho et al., 2004).

Further downstream and close to the estuary Hg levels in sediments drop to a mean concentration of 6.7 μg/g, which is even lower than those encountered in the most upstream part of the river, indicating a dilution effect caused by runoff of catchment soils (Figure 16).

As a consequence of Hg atmospheric deposition on soils close to operations of amalgam burning, it was observed Hg levels in soils up to 690 μg/g, with an average of 270 μg/g in the mining sites (Figure 18). Further downstream Hg levels decrease to a mean value of 14.6 μg/g, indicating that Hg released from the mining sites to the atmosphere present a relatively short residence time as Hg vapour, being mostly precipitated on soils in the vicinities of its source. This can be assumed since Hg level in a soil sample (A249) collected upstream of the mining sites, with 25 μg/g, resembles the Hg levels found further downstream up to the estuary (Figure 18).

As for the assessment of Hg bioavailability through using bioindicators other than fish, like aquatic plants and mollusks, it has been indicated that Hg is being taken up by living organisms in the Talawaan River, as shown by the distribution of Hg in aquatic plants and mollusks (Figures 19 and 20).

Mercury uptake by aquatic plants is particularly evident in cyanidation tailings, where Hg concentrations reach up to 370 μg/g (Figure 19). This is likely a consequence of increasing Hg mobility and biovailability through the formation of mercury-cyanide complexes after cyanidation of highly contaminated amalgamation wastes.

The mean Hg level in aquatic plants of the Talawaan River, 32.3 μg/g, is 13 times higher than the one observed in the most contaminated SSM site in Brazil, according to a previous study (Rodrigues-Filho et al., 2004).

Mollusks also indicate an abnormally high Hg bioavailability in the Talawaan River, with a mean Hg concentration of 2.6 μg/g (Figure 20). This mean value is three times higher than the highest Hg concentration found in a previous study on contaminated coastal sites of the USA (O´Connor, 1993).

Therefore, it is assumed that both factors are contributing to this indicated high Hg bioavailability, namely an anomalous Hg background in the area and the cyanidation of amalgamation wastes forming soluble mercury complexes.

A reduced number of water samples were checked for assessing their quality in relation to guidelines for drinking water. In the sub-area T2, where the main mining sites are located, 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 Brazilian environmental legislation. This is in accordance with the above mentioned hypothesis, since close to the cyanidation plant Hg is clearly forming soluble complexes, becoming therefore susceptible to methylation.

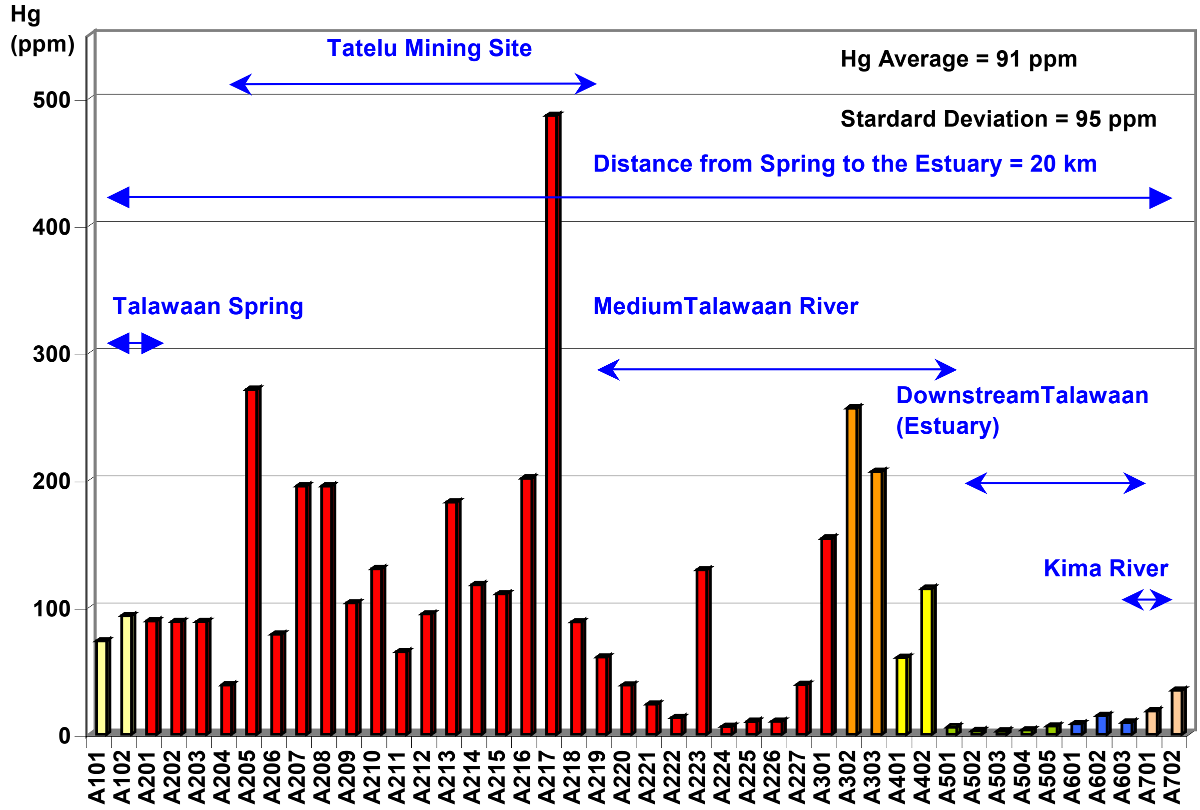


Figure 16 - Distribution of Hg concentrations in sediments along the Talawaan river

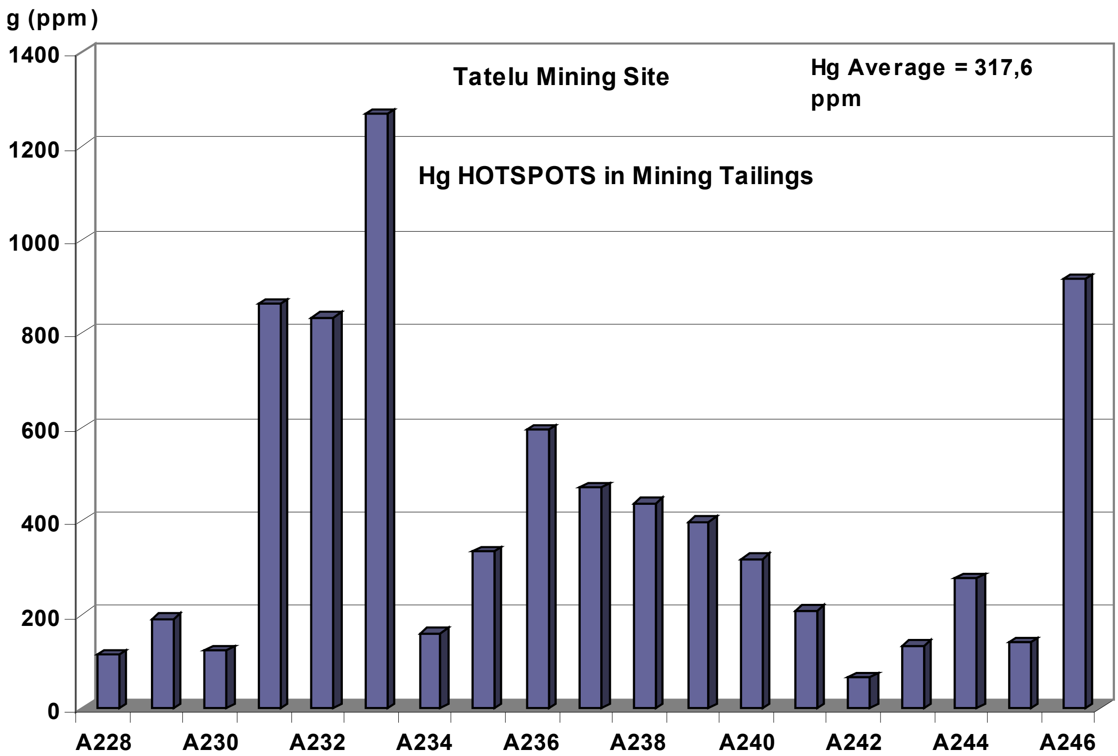


Figure 17 - Mercury Hotspots in Mining Tailings – Tatelu Mining Site

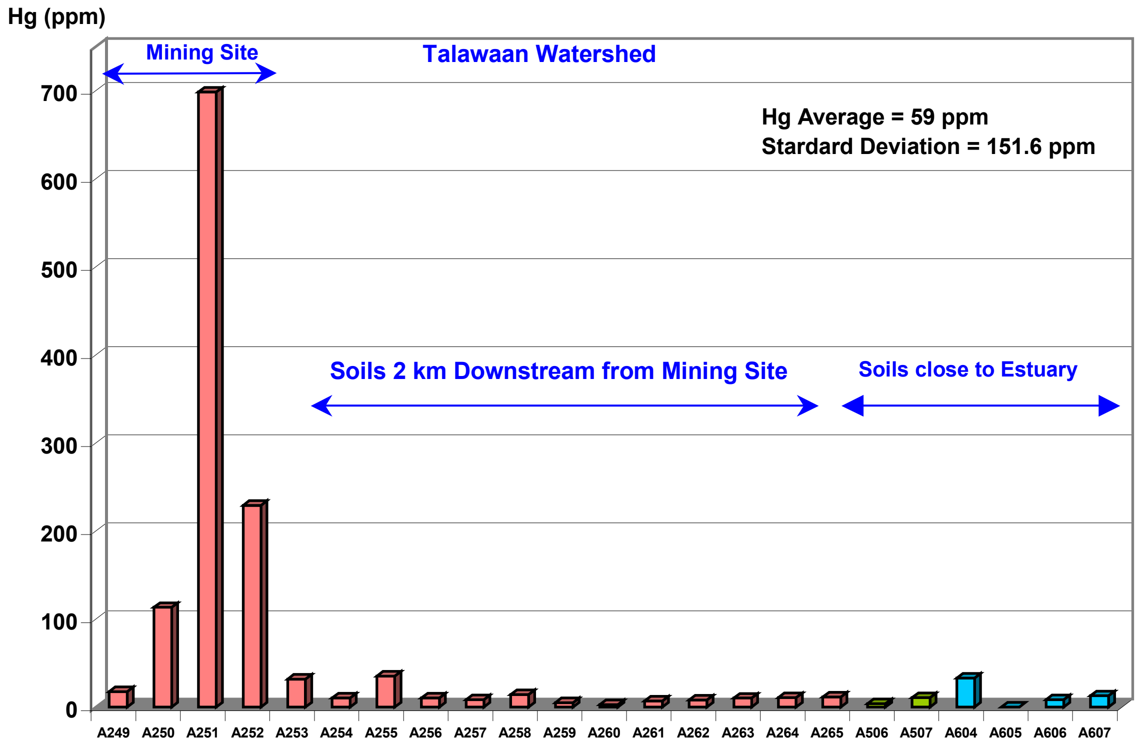


Figure 18 - Mercury distribution in soils of the Talawaan Watershed

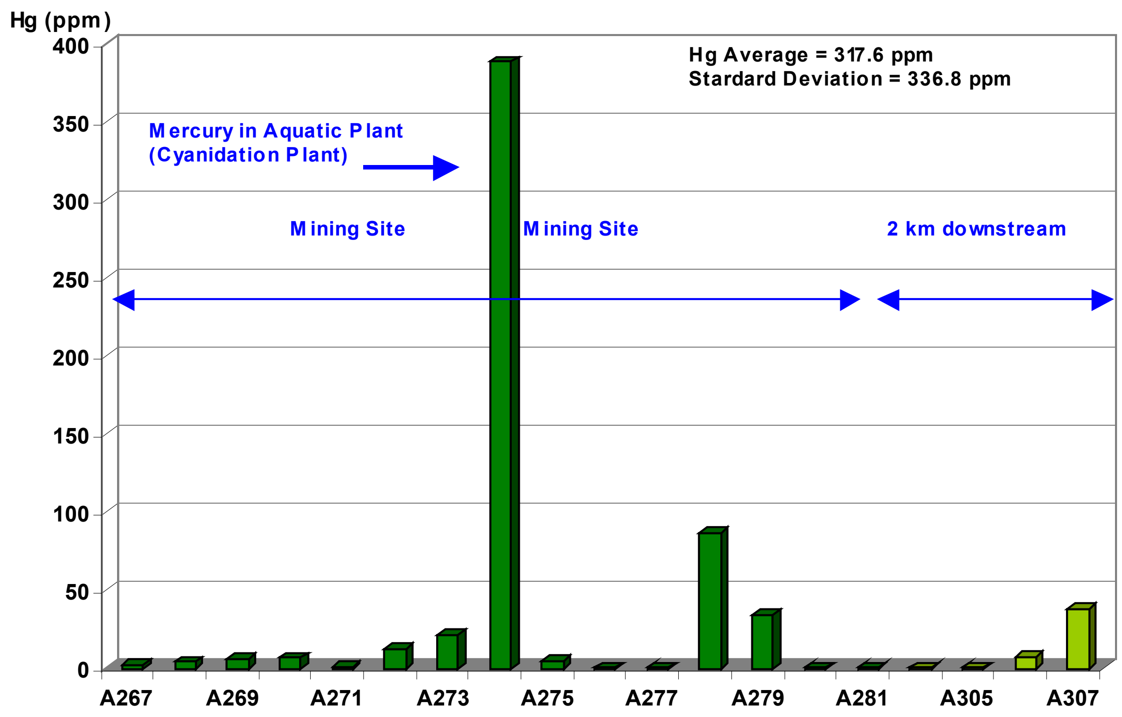


Figure 19 - Mercury in plant tissues growing close to mining operations and downstream

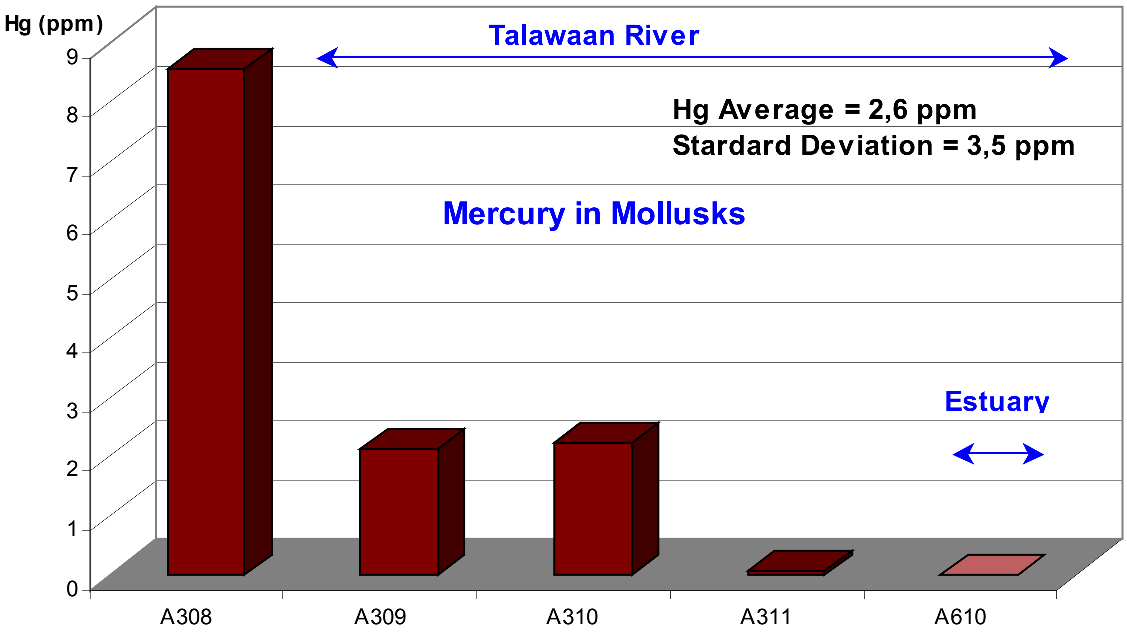


Figure 20 - Mercury in mollusks collected downstream of mining operations

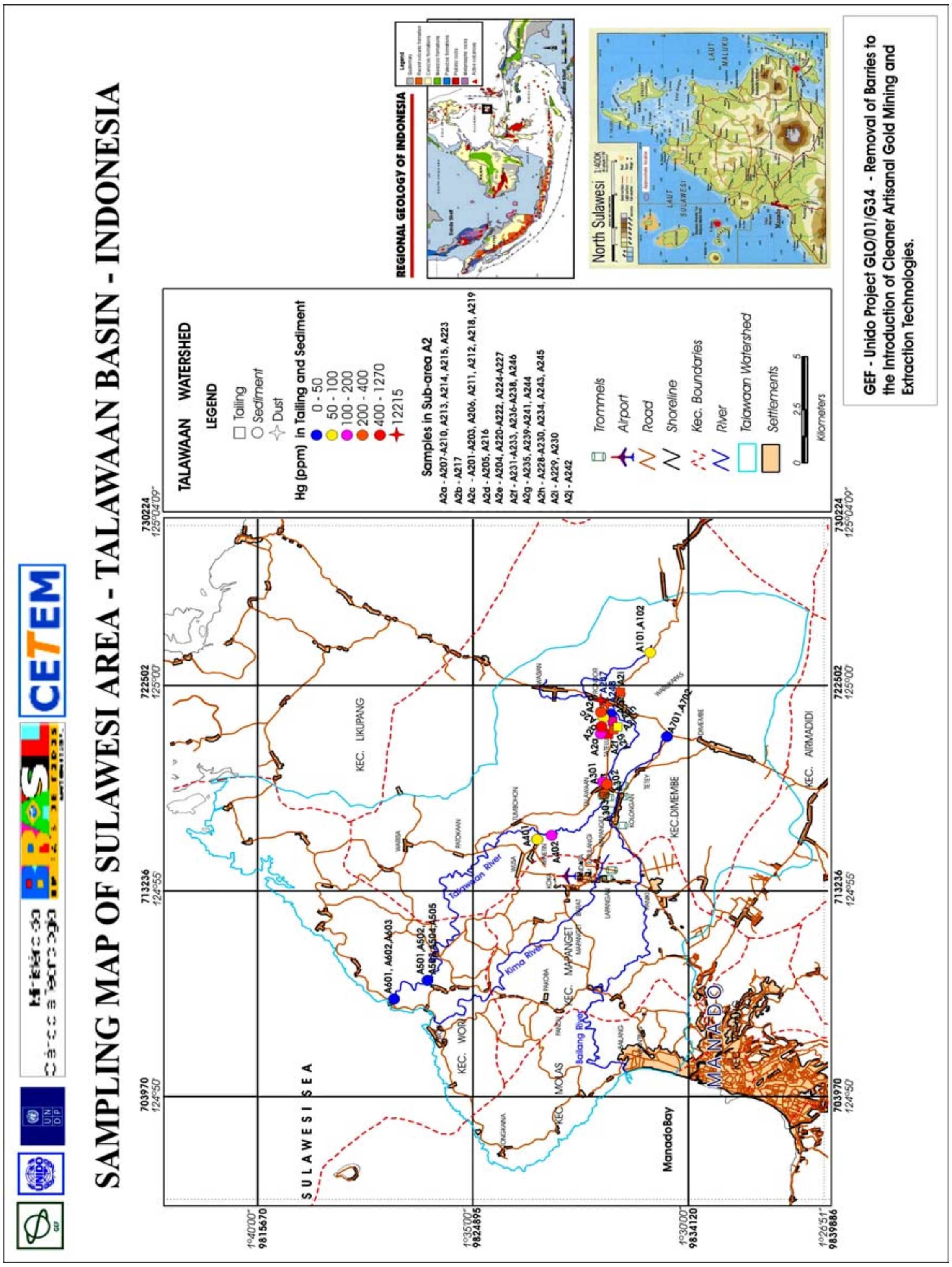


Figure 21 - Mercury distribution in sediments and tailings along the Talawaan Watershed

3.4. Biogeochemistry of Mercury in Central Kalimantan (Galangan Mining Site)

A sampling campaign of soils, sediments, water and biota was conducted in the Galangan mining site, Katingan watershed, consisting of 470 samples split into 264 fish samples, and 206 samples of sediments, soils, water, plants and other aquatic organisms, covering the whole study area, in order to address the identification and location of mercury hotspots.

Investigation from instant matrices like air and water were minimized, since total mercury usually occurs in extremely low levels, or even are undetectable. Therefore, records of mercury emissions, like soils and sediments together with bioindicators, have been preferred for assessing mobility and biovailability of mercury in the environment.

The description of the study sites in the Central Kalimantan, Katingan District is presented in Table 2.

Table 2 - Study sites in the Central Kalimantan aquatic ecosystems and the localization.

	Study Site	Localization
P1	Katingan river, upstream of the mining sites, close to Kosangan district	
P2	Katingan river, downstream of the mining site Galangan, close to Petakbehandang	01°59'34,1"S 113°25'26,2" E
P3	Control area 1	
P4	Flooded open pit in mining site areas	02°00'19,2"S 113°17'10,8" E
P5	Fish market from Palangkaraya; fish maily from Kahayan river	
P6	Kalamanan river, close to Samba region	
P7	Control area 2; close to Orangotangos reservoir, large lake with river contribution	

Mercury Sources

Distribution of mean mercury concentrations in sediments of the Katingan River (study areas P1 and P2), as well as in the Galangan mining site itself (study area P4), sub-area 1, is presented in Figure 22.

Mercury concentrations in sediments are in general significantly lower in this region than in Talawaan, North Sulawesi. This is likely related to both a less polluting mineral processing technique used in Galangan and an existing lower Hg background in the Katingan Basin, as indicated by relatively low Hg levels present in sediments that have been deposited many years before starting SSM activities in the region. Lower sections of sediment cores taken in riversides and floodplains of the Katingan River are assumed to mirror the existing sedimentological conditions prior to disclosure of the gold rush (Figure 23).

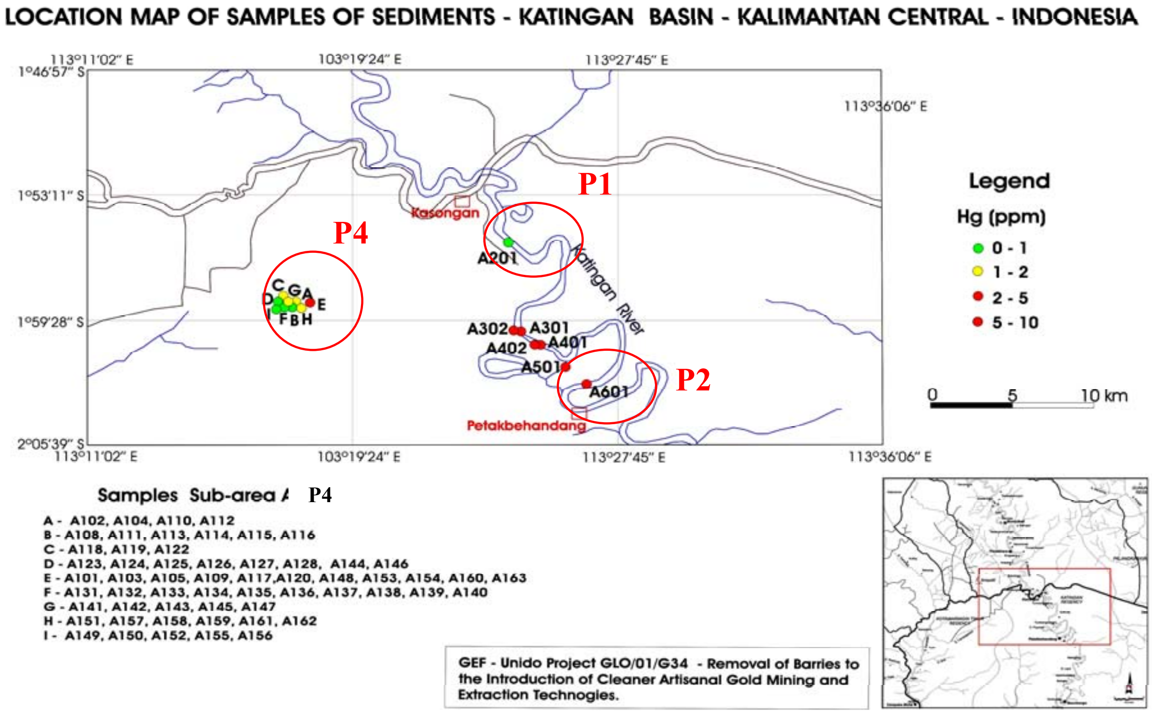


Figure 22 - Mean mercury concentrations in sediments of the study area – Central Kalimantan

Distribution of mercury concentrations in samples of a sediment core from area P2, Katingan River upstream of mining sites, is presented in Figure 23.. Since this core shows significantly lower levels, averaging 0.38 ppm, than in the cores taken downstream of the mining areas, averaging 2.87 ppm, 2.19 ppm and 2.33 ppm, respectively in sediment cores A301, A501 and A601, the Hg range found in core 201 indicates an existing Hg background for this study area (Figures 23 to 26).

Moreover, the sediment cores taken downstream have a similar varying distribution of Hg levels with depth, showing a common peak of Hg concentration between depths from 6 to 12 cm, ranging from 8 ppm in core A301 to 21 ppm in core A501, and to 4 ppm in core 601 (Figures 24 to 26). This Hg peak is likely related to a major Hg release from the mining sites some years ago that probably mirrors a more intense Hg use at the beginning of the gold rush.

Likewise, variations of Hg levels ranging from 0.1 ppm to 1.2 ppm within core A201, which is 1.11 m long, likely reflect a varying Hg background in sediments having as driven force an oscillating Hg contribution from the atmosphere to the aquatic system with time (Figure 23). Since SSM operations started in 1998 in Galangan, Hg levels in deeper core sections might reflect an important contribution from natural Hg sources to the regional environment, among which volcanic activity and mineralogy are to be highlighted.

A wide range of mercury concentrations within unaffected sediment sections, from 0.1 to 1.2 ppm, averaging 0.38 ppm, indicates an uncommon situation that geochemically has no correspondence to previous studies conducted in the Brazilian Amazon (Rodrigues-Filho and Maddock, 1997, Rodrigues-Filho et al., 2002).

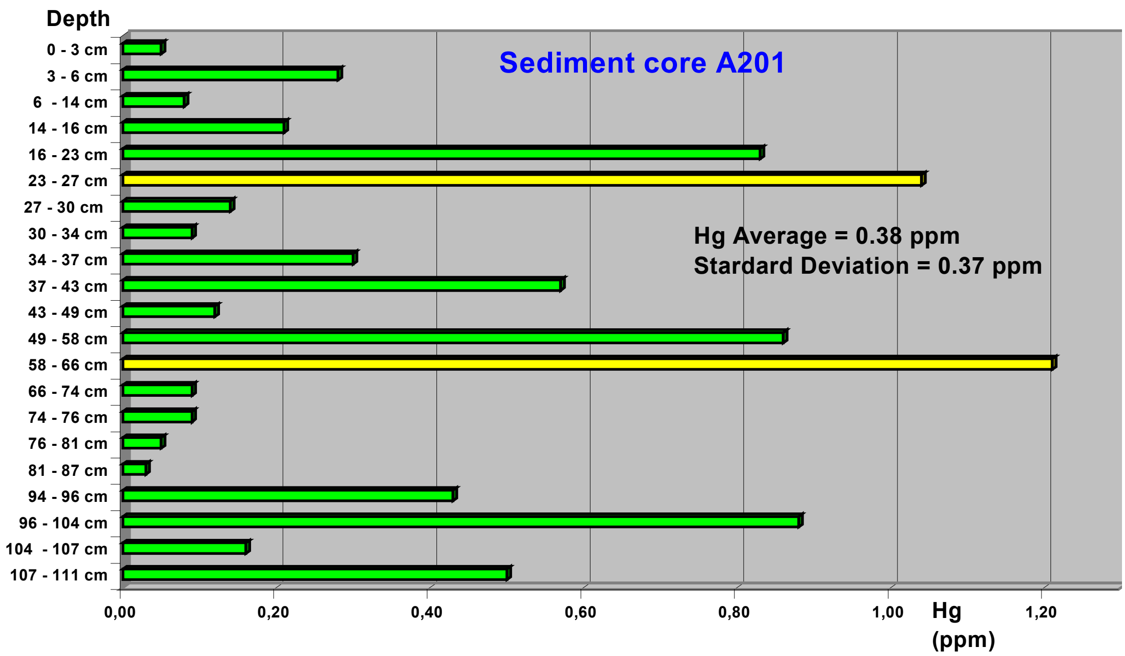


Figure 23 - Mercury concentrations in samples of a sediment core from the Katingan River upstream, area P1

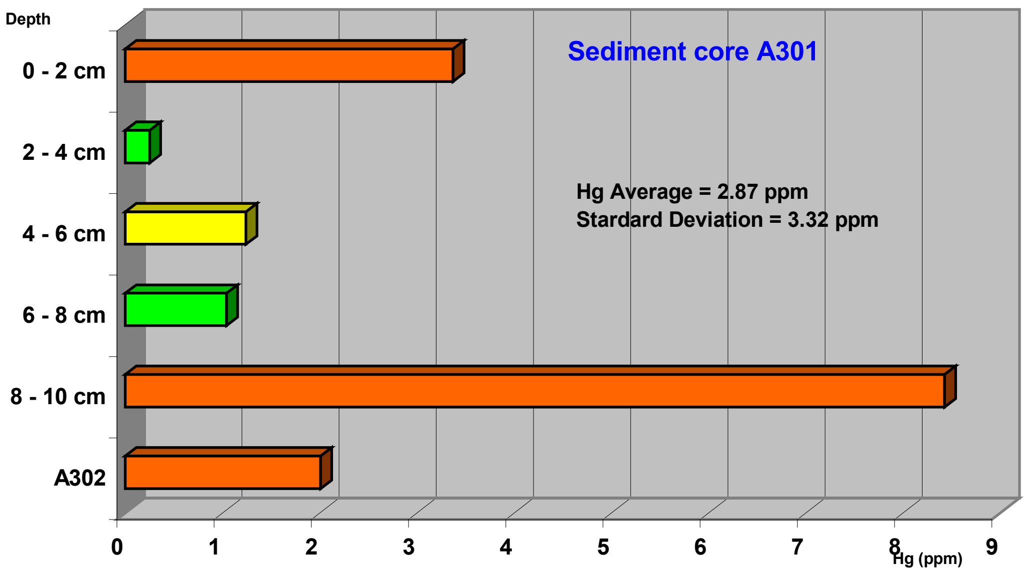


Figure 24 - Mercury concentrations in samples of a sediment core from the Katingan River downstream, between areas P1 and P2

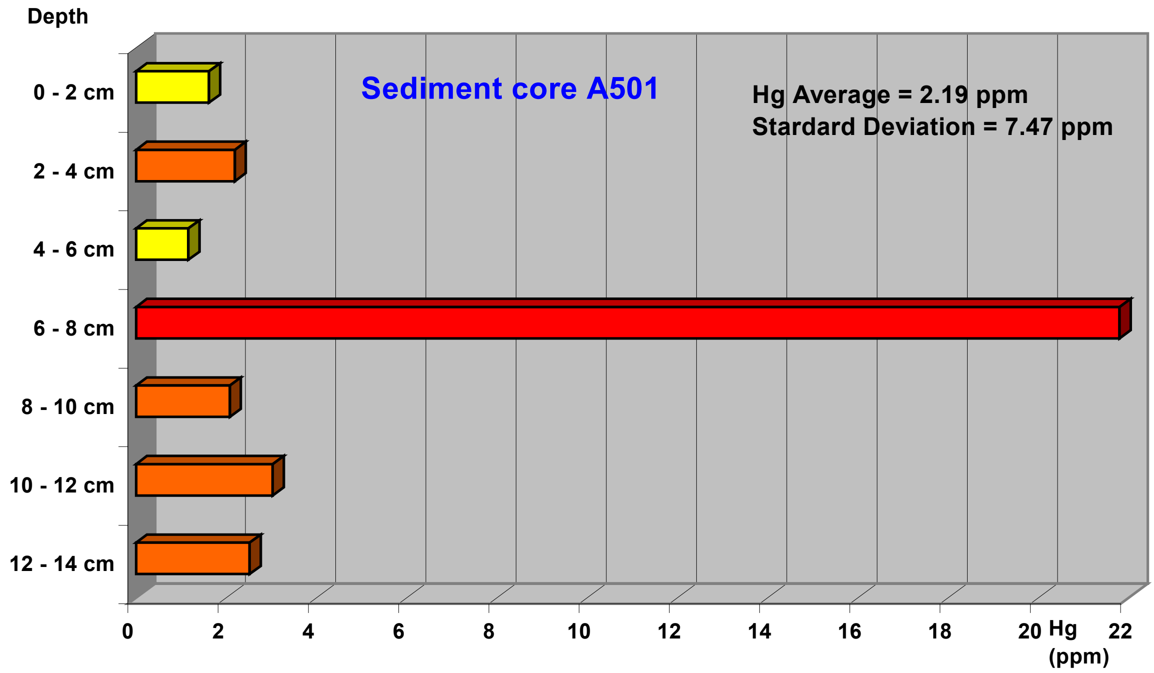


Figure 25 - Mercury concentrations with depth in a sediment core from the Katingan River downstream, area P2

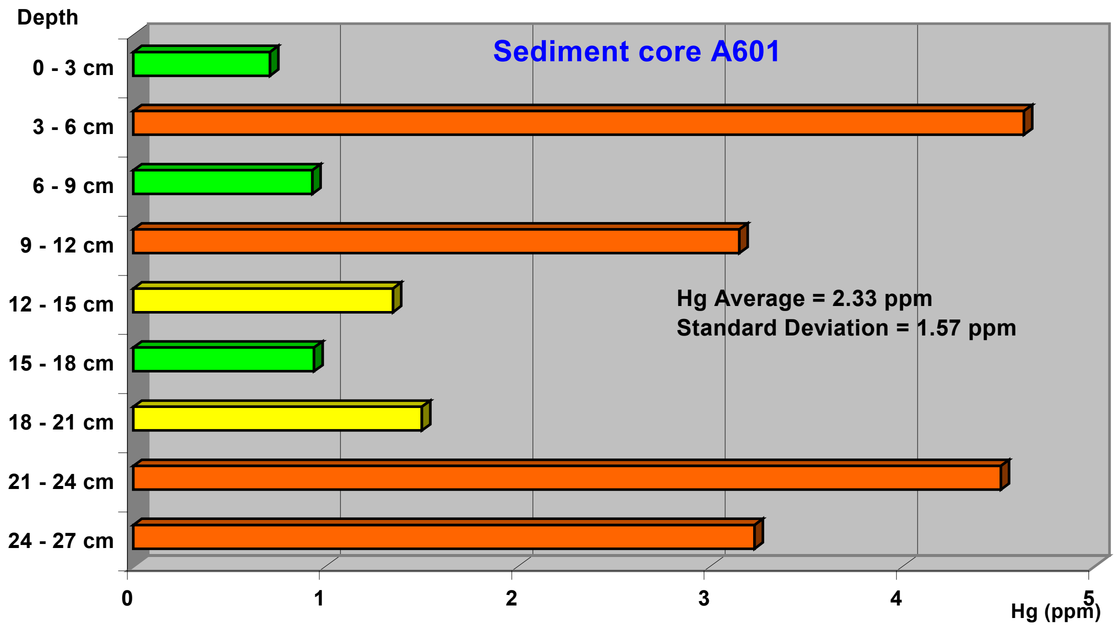


Figure 26 - Mercury concentrations with depth in a sediment core from the Katingan River downstream, area P2

Mercury Releases

The distribution of mercury concentrations in individual sediment samples from the Galangan mining site resembles the levels found along the downstream section of the Katingan River, as presented in Figure 27. This a further indication that sediments from both the mining site and the lower Katingan River are closely related to each other as a consequence of mercury discharges from SSM operations.

Nevertheless, those Hg concentrations in the Galangan region are at least one order of magnitude lower than in Talawaan.

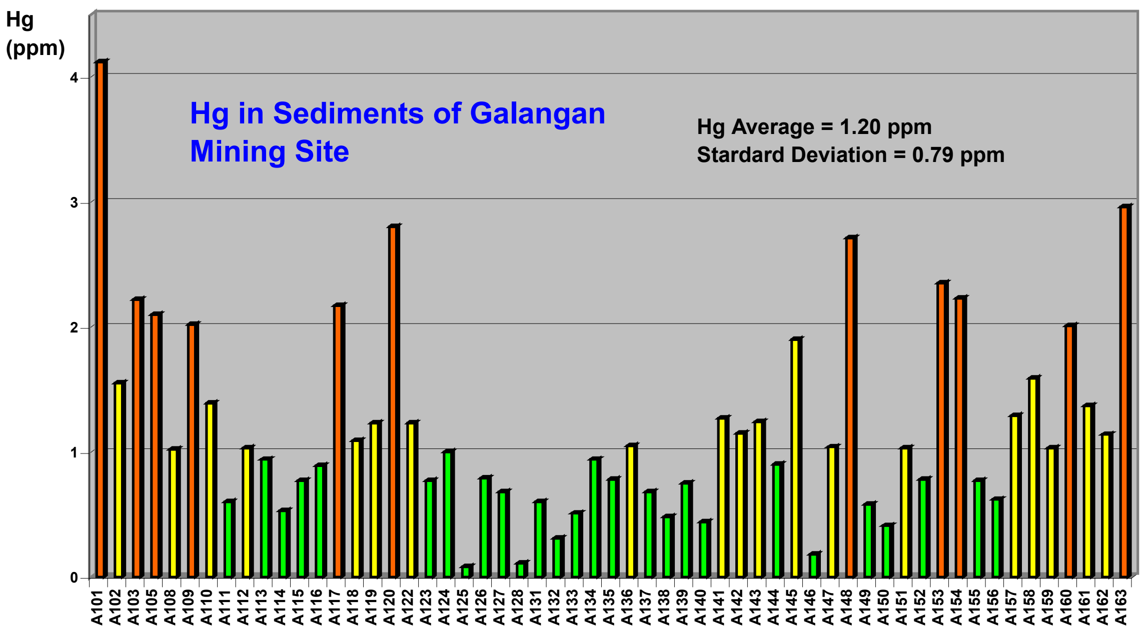


Figure 27 - Mercury concentrations in individual samples of current sediments from the Galangan mining site

A similar situation of Hg contamination in mining hotspots is to be reported for the mining tailings in the mining site in Galangan, as presented in Figure 28, but to a much lesser extent than in Talawaan, principally as a consequence of the mining techniques employed and the local geological setting that indicate a relatively low mercury availability to the environment. This general contamination degree in mining tailings is also lower than the existing one in Brazilian SSM sites (Rodrigues-Filho et al, 2004).

The prevailing sandy composition of the mining tailings that is driven by the type of alluvial deposit with almost no silt-clay fraction is a likely explanation for this relatively low levels, since Hg released during amalgamation finds no particulate surface to be adsorbed on, leading to Hg concentrations even lower than in river sediments (Figure 28).

On the other hand, although a relatively low Hg contamination degree in amalgamation tailings is to be reported, there are strong indications that mercury finds a favorable condition for becoming highly mobile as indicated by the abnormally high levels found in the organic fine cover of the tailings, composed basically of algae. This is an indication that mercury is being dissolved by the organic dark waters of Galangan, which is a potentially favorable condition for increasing mercury bioavailability through methylation (Figure 28).

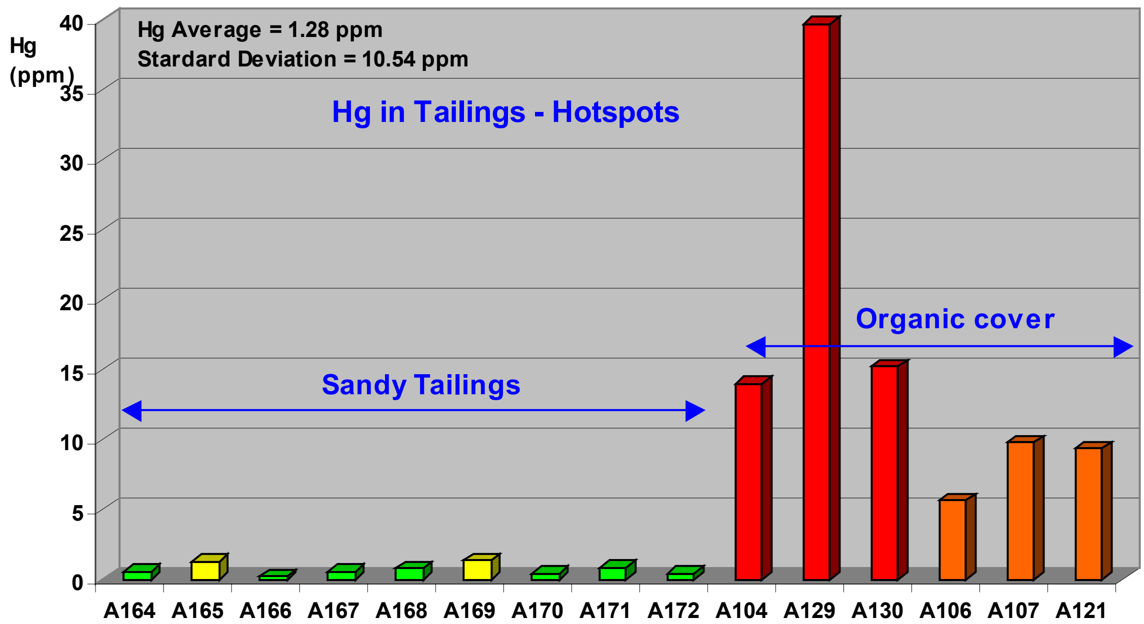


Figure 28 - Mercury concentrations in individual samples of mining tailings from the Galangan mining site

Despite of their high mercury concentrations, the so called *mining hotspots* have been characterized elsewhere as having low mobility and bioavailability provided that prevailing hydrochemical parameters in SSM sites favor the thermodynamic stability of metallic mercury in most aquatic systems. This seems not to be the case in the Galangan mining site, since metallic mercury is likely being oxidized, forming soluble complexes to become available to methylation.

The distribution of mercury concentrations in water samples from both the mining site and the Katingan River supports the recommendation of not carrying out an extensive survey based on water samples (Figure 29). From these results, one could indicate a low mercury mobility in the aquatic system of Galangan, since they fall in a frequently found range (Rodrigues-Filho et al, 2002). However, in contrast, as indicated by the very high Hg levels in organic layers, mercury mobility and potential bioavailability should be reported as abnormally high. This indicated high Hg bioavailability is most likely related to the organic acid content of the dark water drainages in Galangan.

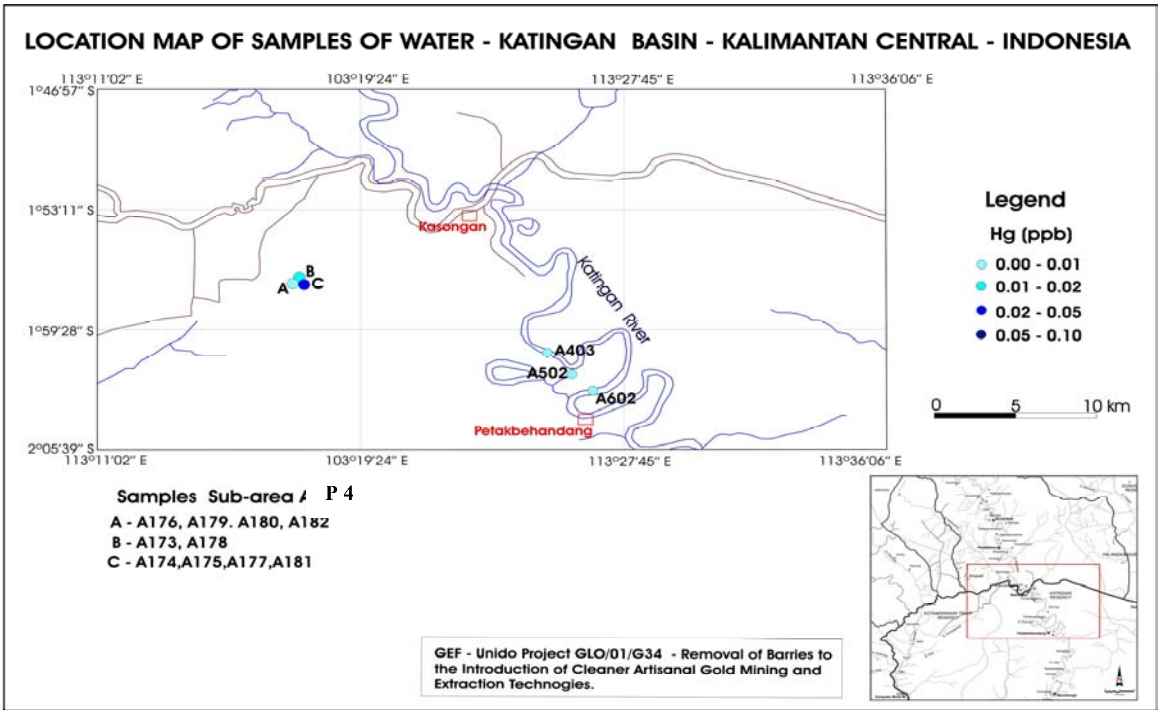


Figure 29 - Mercury concentrations in water samples from the study area – Katingan River and Galangan mining site

Distribution of mercury concentrations in samples of aquatic plants and mollusks from both the mining site and the Katingan River is presented in Figure 30.

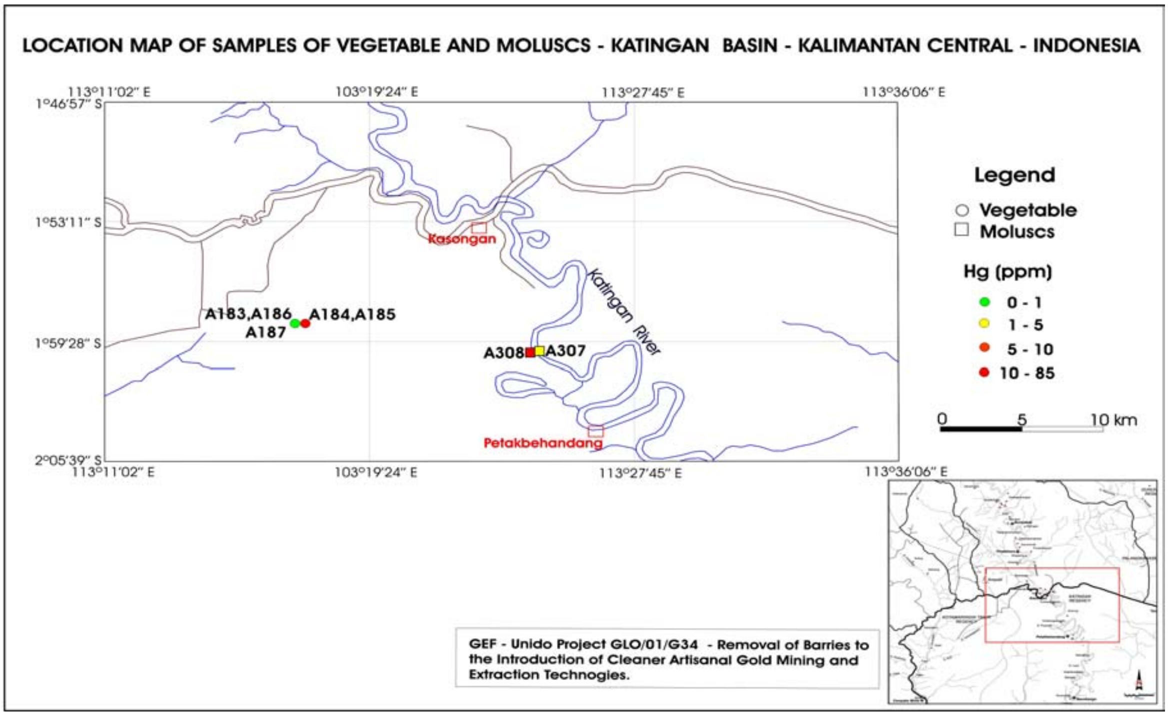


Figure 30 - Mercury concentrations in samples of aquatic plants and mollusks from the study area – Katingan River and Galangan mining site

3.5. Mercury in Fish

The Talawaan river, belonging to the Talawaan watershed, also known as Tatelu region was chosen also considering that previous work (YBCA et al., 2003) showed abnormally high mercury levels in fish from the Talawaan watershed.

It was investigated the fish presence at 7 sub-areas in North Sulawesi, in the Talawaan mining area. Along the Talawaan river, it was collected 156 fish specimens of 11 species (gabus, gete-gete, gold fish, guruo, kesa, lalimata, mujair, nilem, payanka, sepot, supit), one specimen (gold fish) from fish-farming, while 26 specimens of 5 marine species were bought at the fish market in Manado (cakalang, deho, tudê, bobara and malalugis).

In Central Kalimantan, a total of 264 fish specimens of 25 species (banta, baung, bawal, darap, gabus, gold fish, gurame, juah, kalatau, kalui, kapar, karandang, kelabau, lais, lais lintang, lawang, nilem, papayu, patin, putin, saluang, sapat, tahuman, tekung, tongkol) were collected. Thirty-three specimens of six species were bought at the fish market in Palangkaraya. It is important to realize that some specimens came from fish farming inside the Katingan river, such as patin and tahuman species.

It is generally agreed that Hg concentrations in carnivorous fish are higher than in non-carnivorous species (e.g., Watras and Huckabee 1994), due to the indirect Hg bioaccumulation or biomagnification. Some fish species were captured in several sites in reasonable number, as gabus and tahuman, which are classified as carnivorous species. Others, as banta and saluang, feed on benthos and plankton. So, carnivorous species and other species that feed on benthos were collected, as advised by Protocol. On the other side, the Protocol also advises to collect fish according to standardized lenghts for spatial and temporal comparison, but this could not be followed due to scarcity of different fish lengths of a given species.

Fish samples were collected by gill-netting and fishing line with a fish-hook. Each specimen was weighed (Wt), and its length (Lt) was measured at the time of collection. After removing the individual axial muscle (fillet), each sample was placed in polyethylene bags and in ice boxes, and frozen after reaching hotel facilities. The Table 3 shows general information about the fish collection in the study sites.

Table 3 - SSM areas, number of sites and number of fish specimens

Garimpo areas	Number of Sites	Number of samples
North Sulawesi	7	156
Central Kalimantan	7	264
TOTAL	14	420

A total of 389 fish were collected, excluding the fish-market specimens from Manado (n=24), which are mainly from marine aquatic system or freshwater fishfarming. The popular and scientific names, food habit and number of fish specimens collected in both areas are shown in Tables 4 and 5.

Table 4 - Popular and scientific names of species collected in the North Sulawesi, Manado city, Talawaan watershed (T); food habits (FH) when available, and number of specimens collected (n) in each site and total number

Popular name	Scientific name	FH	T1	T2	T3	T4	T5	T6	T7	Total
gabus	*Ophiocephalus striatus*	C				2				2
gete-gete	*Ambassis* sp	C				2	8			10
gold fish	*Cyprios carpio*	O	1						4	5
guruo	*Mugil cephalus*	H			6	7	24			37
kesa	*Anabas* sp	O			3					3
lalimata	*Caranx* sp	C				8				8
mujair	*Oreochromis mossambicus*	O		5	14			4		23
nilem	*Osteochilus hasselti*	O		18						18
payanka	*Ophiocara* sp	C		12	11	1		2		26
sepot	-	-			1					1
supit	-	-					1			1
cakalang	*Katsuwonus pelamis*	C							4	4
deho	-	-							4	4
tudê	-	-							5	5
bobara	-	-							4	4
malalugis	*Decapterus kurroides*	C							5	5
	TOTAL		1	35	35	20	33	6	26	156

Table 5 - Popular and scientific names of species collected in Central Kalmantã, food habits (FH) when available, and number of specimens collected (n) in each site and total number

Popular name	Scientific name	FH	P1	P2	P3	P4	P5	P6	P7	n
banta	*Labipbardus sp.*	O	38	2		7				47
baung	*Macrones microcanthus*	-	2	1			14		1	18
bawal	*Colossoma macropomum*	O					5			5
darap	-	-							1	1
gabus	*Ophiocephalus striatus*	C		5		18			1	24
gold fish	*Cyprios carpio*	O	11				4			15
gurame	*Osphrenemus goramy*	O					3	1		4
juah	*Luciosoma* sp	-		2						2
kalatau	-	-			28					28
kapar	-	-			4			2		6
kerandang	*Channa pleurophthalmus*	-			1					1
kelabau	*Osteochilus melanopleurus*	O		1						1
lais	*Kryptopterus lais*	-		1				5	1	7
lais lintang	*Bagrichthys* sp.	-		1						1
lawang	*Pangasius nieuwenhuisii*	-	18	1						19
nilem	*Osteochilus hasselti*	O	10							10
papayu	*Anabas testudineus*	C			4			1		5
patin	*Pangasius pangasius*	C	1	12			4			17
putin	*Liza vaigienses*	O		2						2
saluang	*Rasbora* sp.	O	4	22					1	27
sapat	*Trisoppterus* sp.	-		4						4
tahuman	*Channa micropeltes*	C		15						15
tekung	-	-	2							2
tongkol	*Euthynnus affinis*	C					3			3
TOTAL			86	69	37	25	33	9	5	264

FH= omnivorous=O, carnivorous=C; herbivorous=H)

The results of total mercury in fish from North Sulawesi and Central Kalimantan garimpo’s areas are shown in Table 6.

Table 6 - Results of total Hg in fish from both study areas (arithmetical mean±standard deviation and range -maximum and minimum values; wet weight)

Garimpo area	N	Mercury (μg/g)	Range
North Sulawesi	130	0.58±0.45	0.01-2.60
Central Kalimantan	264	0.25±0.70	0.004-9.83
Central Kalimantan	263	0.21±0.36	0.004-1.83
Total	389	0.36±0.64	0.004-2.60

The present results show that total mercury concentrations in fish from North Sulawesi are higher than in fish from Central Kalimantan area and the Table 6 shows the minimum and maximum values for Hg in fish in both areas. Considering that highest level was characterized as an extreme outlier, it was excluded. Therefore, one specime from P4 was excluded, resulting a total of 24 specimes from P4. The resulted mean of Hg from Central Kalimantan is 0.21±0.36 μg/g (N=263) and its maximum value is 1.83 μg/g, while in North Sulawesi mean Hg level is 0.58±0.45 μg/g (N=130) and its maximum value reachs 2.60 μg/g. Figure 1 shows mean mercury concentrations in fish from these areas.

Comparisons with global means of Hg in fish, however, may result in a certain misinterpretation, since observations on given species of marine and freshwater fish indicate that all tissue concentrations of mercury increase with increasing age (as inferred from length) of fish (WHO, 1990); it is also strongly affected by fish species and size (length and weight).

The results of total mercury in fish, length and weight from North Sulawesi and Central Kalimantan garimpo's areas are shown in Table 7.

Table 7 - Results of total Hg in muscles (wet weight), length and weight of fish from both study areas (arithmetical mean and standard deviation)

Garimpo área	N	Mercury (μg/g)	N	Length (cm)	N	Weight (g)
North Sulawesi	130	0.58±0.45*	130	9.36±2.84*	130	27.0±46.5*
Central Kalimantan	263	0.21±0.36	263	16.59±13.8	263	170.7±311.3
Total	394	0.33±0.43	393	14.20±11.89	393	123.25±264.66

N= number of specimens. Student's t-test; * $p<0.0001$, between areas

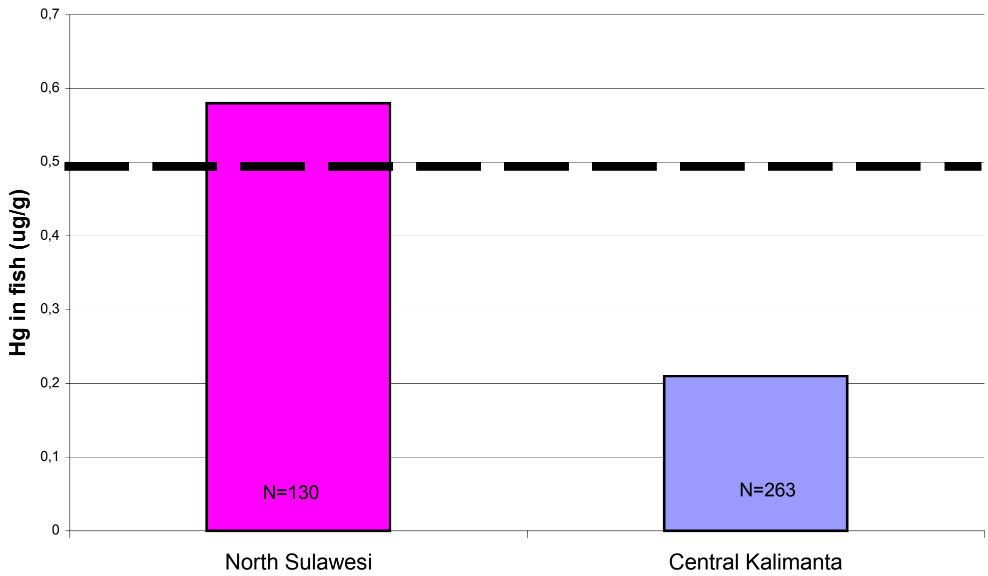


Figure 31 - Hg levels in fish from North Sulawesi and Central Kalimantan

It is well known that freshwater biota is able to accumulate Hg from natural and anthropogenic sources. Maximum background levels for Hg in uncontaminated freshwater fish are in the range of 0.1 to 0.3 μg/g, although considerably higher levels can be found in large predators. The mean concentration of Hg (0.36 μg/g) in fish species from this work was within that range and lower than 0.5 g/g, the Hg concentration in fish recommended by WHO (1990) as limit for human protection by Hg exposure by fish consumption. However, we have to take into account that these species are smaller and lighter than fish from other aquatic systems influenced by gold mining, such as Amazon region (CETEM/IEC, 2004). In addition, among the analyzed fish, 81 specimens, 21% of total fish sampled (389 fish) presented Hg concentrations above 0.5 μg/g. Whereas in Central Kalimantan less than 10% of fish samples showed Hg levels above that limit, in North Sulawesi this percentage increases to more than 45%. It should be considered that fish from North Sulawesi are smaller and lighter than fish from Central Kalimantan, suggesting that Hg bioavaliability in Manado can be higher than in Central Kalimantan.

Tables 8 and 9 present total Hg concentrations in individual fish species (μg/g) from different sites in North Sulawesi and Central Kalimantan, respectively, and the mean Hg levels in fish from different sites.

Table 8 - Total Hg concentrations (arithmetical mean±standard deviation) in individual fish species (μg/g) from North Sulawesi garimpo's areas, Talawaan river watershed

Popular name	Mercury (μg/g)						
	T1 (n)	T2 (n)	T3 (n)	T4 (n)	T5 (n)	T6 (n)	T7 (n)
gabus				1.49±0.4 (2)			
gete-gete				0.60±0.0 (2)	0.51±0.3 (8)		
gold fish	0.04 (1)						
guruo			0.26±0.0 (6)	0.57±0.3 (7)	0.33±0.1 (24)		
kesa			1.2±0.40 (3)				
lalimata				0.37±0.3 (8)			
mujair		0.68±0.3 (5)	0.31±0.1 (14)			0.01±0.0 (4)	
nilem		0.90±0.4 (18)					
payanka		0.84±0.3 (12)	0.73±0.3 (11)	2.60 (1)		0.03±0.0 (2)	
sepot			1.2 (1)				
supit					0.64 (1)		
bobara							0.017±0.0 (3)
cakalang							0.06±0.01 (3)
deho							0.05±0.03 (3)
gold fish							0.03±0.009 (5)
malalugis							0.01±0.003 (5)
tudê							0.03±0.01 (5)
TOTAL	0.04 (1)	0.85±0.41 (35)	0.54±0.39 (35)	0.68±0.63 (20)	0.38±0.18 (33)	0.02±0.01 (6)	0.03±0.02 (24)

N= number of specimens

Table 9 - Total Hg concentrations (arithmetical mean±standard deviation) in individual fish species (μg/g) from Central Kalimantan garimpo's areas

Popular name/ Scientific name	Mercury (μg/g)						
	P1 (n)	P2 (n)	P3 (n)	P4 (n)	P5 (n)	P6 (n)	P7 (n)
Banta	0.06±0.04 (38)	0.03±0.001 (2)		1.29±0.34 (7)			
Baung	0.18±0.02 (2)	0.22 (1)			0.19±0.07 (14)		0.3 (1)
Bawal					0.01±0.002 (5)		
Darap							0.08 (1)
Gabus		0.16±0.03 (5)		1.21±0.42 (17)			0.21 (1)
gold fish	0.02±0.003 (11)				0.01±0.001 (4)		
Gurame					0.01±0.006 (3)		
Juah		0.19±0.04 (2)					
Kalatau			0.17±0.04 (28)				
Kalui						0.19 (1)	
Kakapar			0.12±0.03 (4)			0.26±0.02 (2)	
Karandang			0.15 (1)				
Kelabau		0.11 (1)					
Lais		0.09 (1)				0.25±0.03 (5)	0.14 (1)
lais lintang		0.05 (1)					
Lawang	0.04±0.03 (18)	0.04 (1)					
Nilem	0.02±0.02 (10)						
Papayu			0.18±0.10 (4)			0.20 (1)	
Patin	0.004 (1)	0.01±0.002 (12)			0.09±0.02 (4)		
Putin		0.04±0.02 (2)					
Saluang	0.16±0.07 (4)	0.11±0.06 (22)					0.11 (1)
Sapat		0.09±0.02 (4)					
Tahuman		0.22±0.50 (15)					
Tekung	0.08±0.01 (2)						
Tongkol					0.06±0.002 (3)		
TOTAL	0.05±0.05 (86)	0.12±0.09 (69)	0.16±0.05 (37)	1.24±0.39 (24)	0.10±0.09 (33)	0.23±0.04 (9)	0.16±0.08 (5)

N= number of specimens

According to statistical analysis (One-way Anova; Duncan) the Hg levels in fish from Taldano river (reference area-T6) showed the lowest mercury levels, while T2, a dam, showed the highest mercury levels in fish, and it could be considered as the most contaminated site. There are some gold mining processing units surrounding this site. The Hg levels in the reference site are quite low, although they are from the hydroelectric power plant lake, mentioned, sometimes, as an environment that may show high mercury methylation rate. In addition, T3 and T4 showed higher mercury levels in fish than the reference area (T6). Although T5, an estuarine environment, showed Hg levels not significantly different of the reference area (T6), it should considered as a result linked more with the spread of data than the similarity of data. T7, the fish market in Manado, showed very low Hg levels in marine fish.

In Central Kalimantan area, fish from flooded open pits in mining site areas (P4) showed the highest Hg levels. These open pits are used for gold processing and, also, for fishing, bathing and domestic wastes collected. P1 (Katingan river, upstream of gold mining area), P5 (Palangkaraya's fish market, where fish are mainly from Kahayan river) and P7 (reference area 2) showed similar and lowest Hg levels than P4, while P6 (Kalamanan, close to Samba region, near the gold mining area) showed higher Hg levels. Fish from P3 (control area 1) showed Hg levels higher than P1. While the average of Hg in fish from this area are quite low, the Hg levels in fish from P4, the flooded open pits surrounding garimpos´s area might be considered as the most contaminated site. In addition, miners and their families are living close to those open pits and might consume largely these fish.

Figures 32 e 33 show the total Hg levels in fish from different sites.

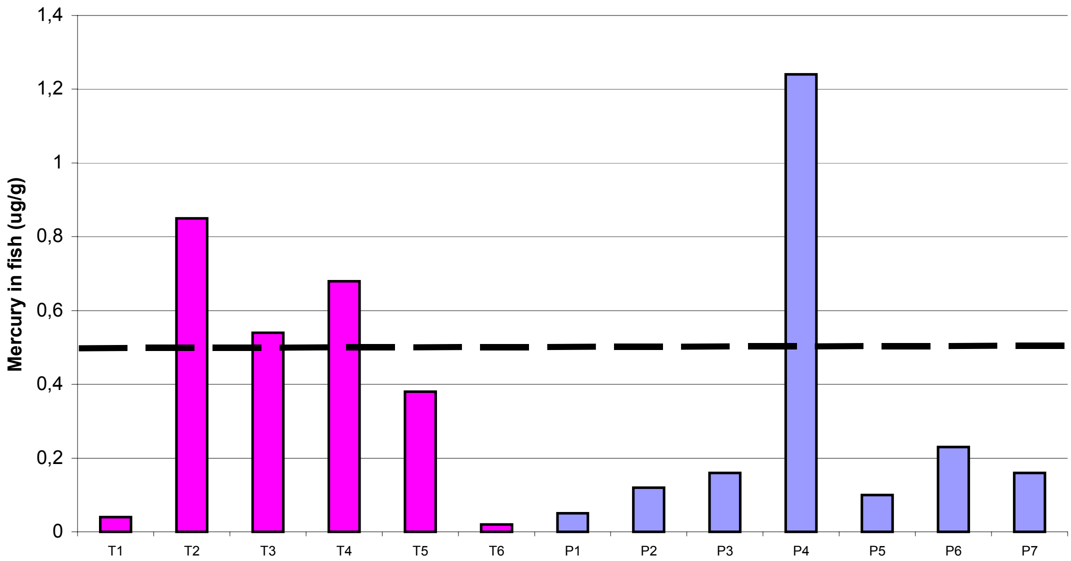


Figure 32 - Hg levels in fish from distinct sites in North Sulawesi and Central Kalimantan

From Tables 8 and 9, it should be noted that few species were caught in more than 2 or 3 sites in reasonable number, meaning that search for specific fish indicator may be a difficult task. As in the same way of some gold mining areas in Amazon or tropical region, these results suggest that, in order to find an indicator of Hg contamination, a search for a site-specific fish species, with more than one species for different sites, could be a suitable approach for spatial analysis. For temporal analysis, one suggest to choose specific species founded in distinct sites.

In North Sulawesi, gete-gete, gruo, mujair and payaka are species caught in more than one site. Comparing the Hg levels among sites, gete-gete showed no differences between T4 and T5, while guruo from T4 showed higher Hg levels than specimens from T3 and T5. Mujair from T6 showed lower Hg levels than from T3, which showed lower Hg levels than mujair from T2. Payanka from T2 and T3 showed higher Hg levels than those from T6. Concluding, the fish species analyzes corroborate with the global means and indicate that T2 as the most contaminated site. However, as shown in Figure 32, the mean of mercury in specific fish species showed the tendency of high mercury levels in fish from all sampling sites and one could suggest that the mercury levels in fish from this area are similar among them, which may reflect the extent of mercury contamination.

In order to search the fish indicator in North Sulawesi, linear correlation was investigated and the results showed Payanka a significant positive relationship between Hg levels and length (0.498; $p<0.01$; $n=26$) and weight (0.627; $p<0.001$; $n=26$). No other species showed positive significant correlation. According with the present results only Payanka could be used as fish bioindicator of mercury contamination in this area.

Figure 33 shows the mean of Hg levels in several fish species from different study sites in North Sulawesi area.

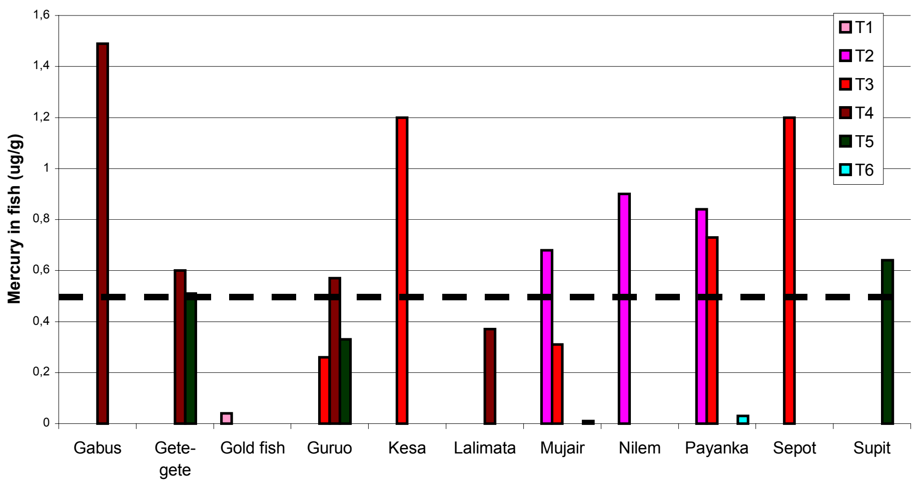


Figure 33 - Hg levels in different fish species from distinct sites in North Sulawesi area

In Central Kalimantan, banta, gabus, gold fish, patin and saluang are species caught in reasonable number in more than one site. However, considering all of specimens collected, as shown in Figure 34, the mean of mercury in specific fish species showed the highest mercury levels in fish from P4. Banta and gabus showed higher Hg levels in specimens from flooded open pits (P4) than from Katingan river, upstream of gold mining area (P1) or from Katingan river, downstream of the mining site Galangan (P2), respectively, although fish from these sites are higher and heavier than specimens from P4. Hg levels in gold fish from Katingan river (P1) are higher than in specimens from Kahayan river (P5), although they are smaller and lighter than fish from Katingan river. Patin from Kahayan river (P5) showed higher Hg levels than specimens from Katingan river downstream of gold mining (P2) but they are higher and heavier. It suggests that Katingan river should more contaminated than Kahayan river. Finally, saluang showed no differences in Hg levels between specimens from P1 and P2; upstream and downstream of gold mining areas in Katingan river.

In order to search the fish indicator in Central Kalimantan, linear correlation was investigated by using nontransformed and logtransformed data for banta, gold fish, lawang and nilem from P1, gabus, patin, saluang and tahuman from P2, kalatu from P3, banta and gabus from P4 and baung, bawal and lais from P6. Since the results showed small differences between nontransformed or logtransformed data, only results for nontransformed data are presented. There is a positive significant correlation for banta from P1 between Hg levels and length (0.4291; $p<0.01$, $n=38$) and weight (0.4628; $p<0.005$, $n=38$) and lawang from P1 between Hg levels and length (0.4697; $p<0.05$, $n=18$). For gabus from P2, positive correlation between Hg levels and length (0.9; $p<0.05$, $n=5$) and weight (0.9; $p<0.5$, $n=5$) were significant. Kalatau showed a positive relationship between Hg levels and length (0.4245; $p<0.05$, $n=28$) and weight (0.412; $p<0.05$, $n=28$) and lais, from P6, showed positive correlation between Hg levels and weight (0.8866; $p<0.05$, $n=5$). One could suggest these fish species as the indicator fish for temporal analysis of Hg contamination in these distinct sites.

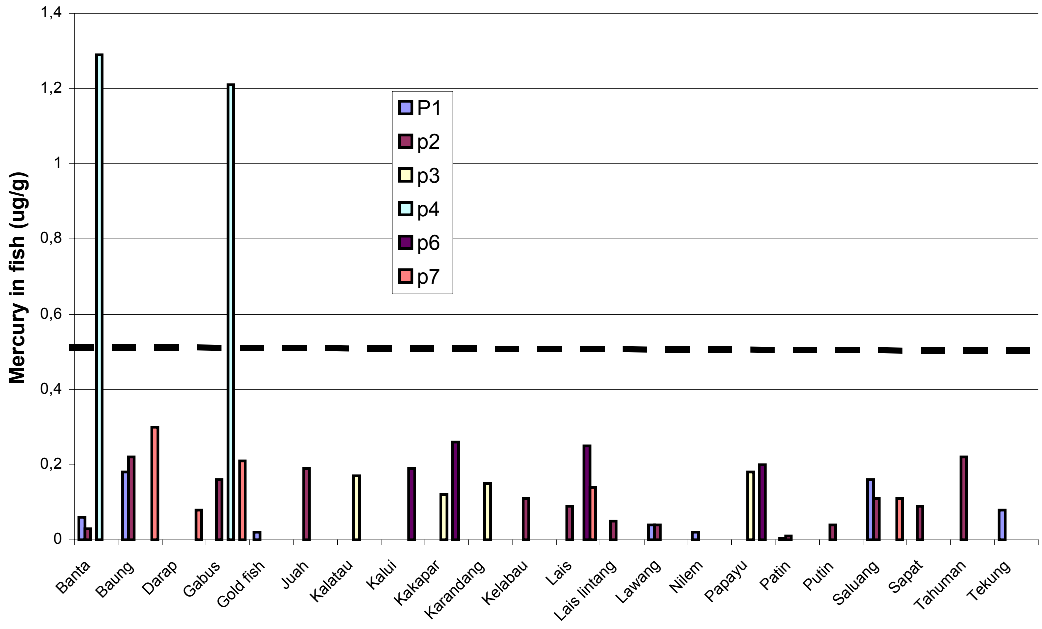


Figure 34 - Hg levels in different fish species from distinct sites in Central Kalimantan area

3.5.1. Human exposure to mercury due to fish consumption

By employing the risk assessment to human health, toxicological, rather than simply the statistical, significance of the contamination can be ascertained. At a screening level, a Hazard Quotient (HQ) approach (USEPA, 1989), assumes that there is a level of exposure (i.e., RfD = Reference of Dose) for non-carcinogenic substances below which it is unlikely for even sensitive populations to experience adverse health effects. The MeHg RfD value is 1E-04 mg.Kg-1.d-1 (IRIS 1995) and its uncertainty factor is 10 and its confidence level is medium. Uncertainties of the RfD statistics have been reported, suggesting an under-estimation of RfD for Hg presented in IRIS, 1995 (Smith and Farris 1996). However, other authors suggest that there is no safe human exposure to MeHg and that of all living species, human appear to have weakest defenses against MeHg (Clarkson 1996). Considerable gaps in our knowledge about this remain. Our approach, therefore, is to use the human risk assessment proposed by USEPA, at screening level. HQ is defined as the ratio of a single substance exposure level (E) to a reference of dose (E/RfD). When HQ exceeds unity, there may be concern for potential health effects. The estimated exposure level was obtained by multiplication of 95th percentil upperbound estimate of mean Hg concentration considering all fish as suggested by USEPA (1989), by the adult human ingestion rate for local populations. Most of the works about riverside population assume consumption rate close to 0.2 Kg.d-1. However, one could considered reasonable suppose that in North Sulawesi most people consume fish from market, mainly marine fish or freshwater from fish farming, rather than those small fish from the study sites. There fore, it could be reasonable to assume a fish comsuption rate close to 0.05 $kg.d^{-1}$ related to freshwater fish.

In Central Kalimantan, it should consider that miners living close to the P4 study site may consume fish caught in those flooded open pits. As they are not riverside population, but considering the poverty, one could assume the fish consumption rate close to 0.05 $Kg.d^{-1}$. Finally, the intake dose is estimated by dividing that product by 70 kg, considering the weight average human adult. Although total mercury was quantified in fish, it has been demonstrated that about 75-95% of total mercury is methylmercury in fish muscles. Thus, in a conservative approach, it has been assumed that total mercury in fish represents methylmercury. The resultant HQs for MeHg are shown in Table 10.

Table 10 – MeHg Hazard Quotient due to fish ingestion in North Sulawesi (NS) and Central Kalimantan (CK) sampling sites

Garimpo's area	RfD	Intake Dose	HQ
NS- total	1E-04	4.64E-04	4.6
NS- Fish market	1E-04	2.86 E-05	0.3
CK-total	1E-04	2.43E-04	2.4
CK-P4	1E-04	9.93E-04	9.9
CK-fish market	1E-04	9.29E-05	0.9

HQ resulted above the unit for North Sulawesi total sampling, but the fish market consumption. For Central Kalimantan, both total and P4 sampling site, HQ resulted above the unity, 2.4 and 9.9, respectively, which means that population are under hazards due to fish consumption. On the other hand, fish market showed HQ below the unit, suggesting that hazards for consuming fish from Katingan river may be increased compared to consumption of specimens from Kahayan river. The population that may consume fish from the flooded open pits (P4) are under the highest estimated hazards (HQ=9.9) and the local population should be advised for avoiding consumption of fish from those pounds. The picture will be even wont if one consider the usual fish comsuption in the riverside population (close to 0.2 kg/d), increasing the hazard quotient to close 40, which means that population is sender higher health hazard.

In a previous study (Bidone et al. 1997) showed the estimates of Hg concentration in blood and in hair from contaminated site, using the single-compartment model (WHO 1990) through which the steady-state Hg concentration in blood (C) in $\mu g.l^{-1}$ is related to the average daily dietary intake (d) in µg of Hg, as follows: $C = 0.95 * d$. Hair concentrations of Hg are proportional to blood concentrations at the time of the formation of the hair strand, and blood-to-hair ratio in humans is about 1 to 250, but appreciable individual differences have been found (WHO, 1990). A synthesis of the estimates to Hg concentration in blood and in hair using the single-compartment model for North Sulawesi (total and fish market) and Central Kalimantan (total, P4 and fish market) is shown in Table 11.

Table 11 - Hg concentration in fish; estimated average Hg daily intake (d); estimated blood Hg concentration (b) and estimated hair Hg concentration (h).

Garimpo's areas	Hg in fish* ($\mu g.g^{-1}$)	d ($\mu g.d^{-1}$)	b ($\mu g.l^{-1}$)	h ($\mu g.g^{-1}$)
NS-total	0.65	32.5	30.8	7.7
NS-Fish market	0.04	2.0	1.9	0.5
CK-total	0.34	17.0	16.1	4.0
CK-P4	1.39	69.5	66.0	16.5
CK-Fish market	0.13	6.5	6.2	1.5

* = 95 percent upper confidence limit on the arithmetic mean

The background level in hair falls in the range of 1-2 µg/g (WHO, 1990). Hazardous effects on fetus are likely when 20 µg/g is analyzed in the hair of pregnant women. WHO (1990) reports that 50 µg/g Hg in hair is an adequate threshold to observe clinical effects and that child-bearing women with Hg concentrations in hair above 70 ug/g exhibit more than 30% risk of having neurological disorder in the offspring. Levels of 10 µg/g must be considered as the upper limit guideline for pregnant women (WHO, 1990). Recent evaluation considers 5 µg/g Hg in hair a safety guideline for pregnant women (Yagev, 2002), whereas 6µg/g has been considered the Limit of Biological Tolerance (LBT) for general population (WHO, 1990).

The estimated Hg levels in hair in CK total is higher than the LBT, but lesser than the upper limit guideline for pregnant women. The NS and CK fish market are close to the levels found in non exposed population. CK total showed Hg in hair below 5 µg/g Hg, a safety guideline for pregnant women and below the LBT(6µg/g). CK-P4 showed the highest levels, higher than the upper limit guideline for pregnant women, but lesser than levels associated with threshold to observe clinical effects.

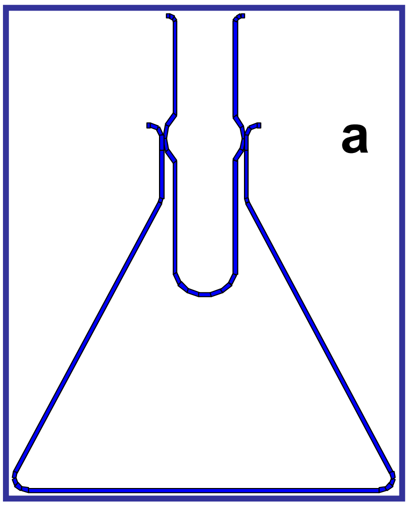
Hg levels in blood and in hair of the average population were estimated by using the one-compartment model associated to the results of Hg levels in blood in the population of NS (30.8 µg/L) and of CK (16.1 µg/L) and the Hg levels in hair of both populations, respectively. The Hg in blood resulted close to 23µg/L and about 6µg/g in hair. These results showed good correspondence with the Hg determination in blood and hair of the population (see 3.7.3. Most of the population from both areas showed Hg levels in blood below 25µg/L and in hair below 10 µg/g, except the amalgam smelters of both areas, which showed higher levels of Hg in blood and in hair, besides identified groups as critical for Hg exposure. In addition, it should be considered that up to 60% of Hg found in the hair of the amalgam smelters refers to inorganic mercury.

3.6. Mercury semiquantitative determination in fish samples in Manado, Indonesia Training of local users

Mercury analysis in soil and sediment samples, though the spectrophotometry methodology of atomic absorption, presents some operational difficulties as to the distance to the sampling object, analytical costs and readiness, specially when the necessary number of samples is very large. The distance from the field to the laboratory facilities usually implies in long-term, high-costs packaging, conservation and transportation procedures that brings great difficulty to the analytical procedure of a large number of samples.

Therefore, CETEM developed an analytical field procedure that fulfills all the above conditions. The proposed method consists of a semi-quantitative colorimetric method.

To determine mercury concentration in fish, 10 g of sample is digested with an oxidant mixture, containing sulfuric acid, nitric acid and vanadium pentoxide (Figure 35a). To the clear solution obtained, containing ionic mercury, a reduction reagent (acid solution of stannous chloride) is added and elemental mercury formed is forced by an air stream (Figure 35b). The mercury steam is forced to go covered with emulsion containing cuprous iodide. The color intensity formed by the complex is proportional to the mercury concentration in the sample.



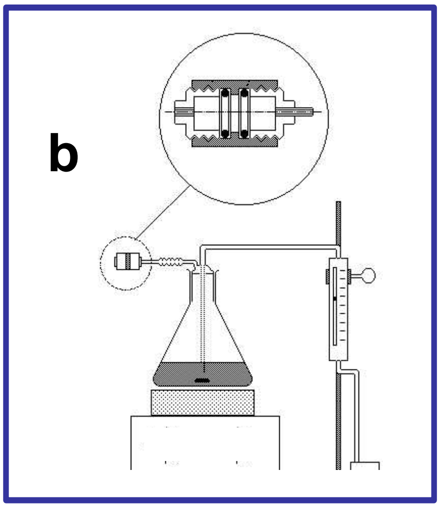


Figure 35 - Digestion system **Figure 35b - Determination system**

At the end of the operation, the operator is capable to classify the sample according to the WHO recommendations, by comparing it with the color developed in similar analytical systems, containing standard solutions. Figure 36 shows the range of colors resulting from the analytical tests.

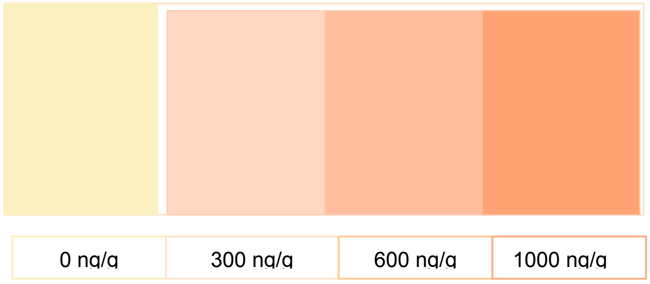


Figure 36 - Similar colors to those developed in the detecting papers

After determination, fish samples can be classified into 3 groups according to Table 12.

Table 12 - Sample classification according to mercury content and the WHO recommendations

Classification	Mercury content (ng/g) of fish
Proper for frequent consumption	Lower than 300
Proper for eventual consumption	Between 300 and 600
Not proper for consumption	Higher than 600

The semiquantitative method was compared to the conventional analytical method (CVAAS), whose performance was checked using Standard Reference Materials of fish muscle and liver fish (Squalus acanthias) produced and distributed by National Research Council Canadá (NRC-CNRC), named DORM-1 and DOLT-2. Participation on the Mercury Quality Assurance Program (MQAP), coordinated by Canadian Food Inspection Agency has been used for the quality assurance of the quantitative method since January 2000.

A similar work developed in Itaituba, Brazil, was developed in Manado, Indonesia. The training was performed in the laboratory of the Balai Laboratorium Kesehatan – Manado, that was arranged by the host institution(Yayasan Bina Cipta Aquatech). Eleven participants from local institutes (Yayasan Bina Cipta Aquatech, Faculty of Fisheries and Marine Science, Sam Ratulangi University, Loka Budidaya Air Tawar, Provincial Environmental Impact Protection Agency Environmental Health Academic and Provincial Health Agency, Balai Laboratorium Kesehatan) were trained in the method and participate in a small application study.

The technical activities were developed in the period 09/09 to 09/20/2003 by Allegra Viviane Yallouz and Débora Maia Pereira, from CETEM.

The training was done focusing on theoretical concepts, practical works, and good lab practices. Each participant received the detailed work instructions in English. For further training, this instructions manual was already translated into Indonesia language by Dr Limbong.

The training program was performed in a similar mode that done in Itaituba: the theoretical concepts were discussed using posters placed on the lab walls and during formal lecture and round table discussion. The main content was:

- Comparison with usual methods
- The importance of mercury determination in fish
- The different toxicology of mercury species
- The chemical pathways of mercury in the environment
- Method's applicability
- Method's advantages and limitations
- WHO recommendations and the Brazilian Laws regarding mercury level in fish
- Quality assurance of the results
- Possible applications

The practical training was performed giving individual training for each participant starting with a practical demonstration of the use. Then, each operator participated on an exhaustive practical training in the use of the determination system until the complete domain of the system using mercury aqueous solutions with well known concentration.

3.7. Health Assessment

3.7.1. General health situation

Doctors, nurses, engineers, teachers and participants were interviewed to identify possible health effects in relation to the mining activities.

The sociological report gave some valuable information about the population in Kalimantan (Rachmadhi P 2003). But the information for Sulawesi was completely misleading. Contrary to the report not only young men worked in the mining areas. Older men, and quite a few women worked there too. The main problem of the Sulawesi area, the intensive child labour was not mentioned at all. It might be doubted, whether the sociologist was at all profoundly investigating in the area.

The infrastructure in Karang Pangi is poor, but sufficient to perform the examination. In Tatelu the infrastructure is more favourable.

The regional health authorities supported the project in Kalimantan. But on the national level there was no support for the project. When asked for support before the start of the project, the Ministry of Health did not support the health assessment.

Health care system in the Central Kalimantan mining area of Galangan

At the moment 8.200 people are living in the village of Kereng Pangi, and approx. 1.200 in the widespread mining area of Galangan (2.000 ha). Most of the miners are men in their twenties and thirties, less women live in the mining area, and the children in the mining area are mainly young. In the village of Kereng Pangi the male/female ratio is nearly equal (4.300 male/ 3.900 female). 200 neonates (0-1 years of age), 800 children (1-6 years) and 1.200 children 6-12 years live in the area.

There is one local health centre in Kereng Pangi. Doctor (Dr. Robertus Pamuryanto) has 9 nurses and 2 midwifes. The centre is responsible for mother-child care, including pregnancy and immunization programmes (DPT, Polio, BCG, Hepatitis B). Diseases such as Malaria and Tuberculosis can be treated there. But the diagnostic procedures such as microbiological tests or x-ray have to be carried out in the next hospital. The health centre is poorly equipped. It is not equipped to treat any serious accident. It is absolutely not equipped to diagnose mercury intoxication, nor can it treat such a condition. Traditional healers (dunkun) are an essential part of the health system.

The next hospital is in Kasongan. Severe cases have to be transferred to Palangkaraya. HIV test can only be performed in Indonesia in two laboratories in Jakarta

General health problems (Galangan area)

The main health problems in the area seem to be:

- Dangerous open pits, approx. 4 lethal accidents occur each month in Galangan.
- Car, motorbike and truck accidents are very common. The traffic conditions are difficult, many cars, motorbikes and trucks are in a bad technical condition. On the road fast cars such as jeeps and trucks share the mainly narrow roads (at night very dark) or off roads with motorbikes, bicycles and pedestrians. There is no infrastructure to rescue and treat any kind of severe accident.
- Infectious diseases, mainly malaria is widespread. Malaria is diagnosed clinically and treated orally with Chloroquine and Quinine. Tuberculosis is with an estimated rate of 5-10 cases in a population of approx. 10.000 endemic, but not epidemic. Tuberculosis is treated under a governmental programme. According to the WHO scheme daily observed treatment (DOT) with quadruple treatment for 2 months (Isoniazid, Rifampicin, Pirazinamid, Etambutol) and follow-up double treatment for 4 month (Isoniazid, Rifampicin) is performed.
- Asthma is fairly common as well. Mainly young people, children as well as workers do or did suffer from Asthma. Oral treatment is prevailed

(Salbutamol). The asthma incidence is higher then expected. The asthma incidence in Kalimantan is higher then in Sulawesi.

- Sexually transmitted diseases (STD) seem to be common. It is estimated that more then 120 sex workers are working in Galangan. 2 HIV positive prostitutes are reported (without treatment). The amount of Hepatitis B and Hepatitis C cases is unknown due to missing laboratory facilities, but Hepatitis seems to be prevalent. Syphilis is common, the sex workers receive regular antibiotic treatment (Kanamycin). One of the nurses of the local health centre is in charge of the sex workers. Safer sex campaigns are unknown.
- The dental status of most people is disastrous. Old people usually only have ruins or stumps left, most adults have severely damaged teeth. Some children have fairly good teeth, other children have a mouth full of rotten teeth.
- Due to insufficient sanitary conditions diarrhoeal diseases are very common. But it is not a major cause of mortality.
- Pneumonia, parasitism, skin diseases, hypertension, upper respiratory infectious and are other important diseases in Galangan.
- Since the population is very young, heart diseases and cancers are rare.
- Smoking is an epidemic habit of nearly all adult men.

Children's health (Galangan area)

25% of the population in the area are children under the age of 12. The main health problems of children in Galangan seem to be:

High exposure to mercury in the area. Children to have access to fluid mercury, they play with this mercury with their hands. They live within the houses where panning or amalgam smelting is carried out, therefore they are also exposed to mercury fumes.

At the age of 15 teenagers start to work in the area as miners with contact to mercury. In Kereng Pangi most children do go to school. In remote areas of Galangan not all children go to school, and begin to work in the mining areas at a very young age. This is child labour at its worst limits, partially physically very hard, partially related to high exposure of mercury. Accidents related to work are a health hazard for these children.

Due to poor sanitary conditions infectious diseases like gastro-intestinal infections and malaria are very common and are a risk for children's health.

Infant mortality can be estimated, in 2002 5 children died in a population of approx 1.200 children.

Hygienic and social problems (Galangan area)

The interviews showed some other problems:

- Poor sanitary conditions are a health hazard.
- The drinking water in Kereng Pangi is sometimes turbid, which is a sign of insufficient hygienic quality. The drinking water is taken from 400 different deep wells within the settlements.
- 10 % of the houses and huts in Kereng Pangi have no toilets. Proper disposal systems for waste including excrement's are missing. Waste is disposed outside the houses and burned.
- In the hilly landscape of Galangan many small water pools exist, containing mercury from panning processes. Human excrements run from the huts into these pools. This water is used for drinking purposes in the area. The water in Galangan area should not be used for drinking purposes.
- The pools are certainly an excellent habitat for transmitters of vector borne diseases, like Malaria.
- 90 % of the huts in Galangan have no toilets. Proper disposal systems for waste including excrement's are missing. Waste is disposed into the pools or just dumped.
- Dark fumes emitted from motorcycles, trucks and burning waste. These fumes contain small particles and PIC's (products of incomplete combustion) and are causing damage to the upper and lower airways.
- Small scale gold mining operations are illegal. Legalisation does not seem to be of major public interest.
- Corruption is still common, and small scale miners are more vulnerable to corruption, since their work is considered as illegal.

Health care system in the Northern Sulawesi mining area of Tatelu

At the moment 18.000 people are live in the villages of the Dimembe district (Tatelu, Talawaan, and 17 others villages). 2.000 children (0-5 years) live in the area. The amount of miners is estimated between 200 and 2.000 next to Tatelu. Since the mining area is still expanding, 2.000 miners might be a good estimation. Most of the miners are men over 15 years, mainly in their twenties and thirties, fewer women live in the mining area, and even less children.

There is one local health centre in Tatelu. Doctor Louisa M. Pongajouw has 16 nurses and 9 midwifes for the Dimembe district. Three private doctors and 1 dentist are working in the area as well. The centre is responsible for mother-child care, including pregnancy and immunization programme (DPT, Polio, BCG, Hepatitis B). Disease such as Malaria and Tuberculosis can be treated. The health centre is fairly equipped, it is equipped to diagnose tuberculosis, but it can not treat any serious accident. It is not equipped to diagnose mercury intoxication, nor can it treat such a condition.

Health promotion is a task of the health centre. Two campaigns to raise awareness for the mercury as a health hazard took place in the last years. Public servants and miners were informed about the health risks. No actual program is running.

The next hospital is in Manado.

General health problems (Tatelu area)

The main health problems in the area seem to be:

- Due to inappropriate security measures, tunnels collapse. Approx. 2-5 lethal accidents happen each year in the Tatelu mining area in these dangerous tunnels.
- Car, motorbike and truck accidents are very common, as in Kalimantan.
- Infectious diseases, mainly malaria is widespread. Malaria is diagnosed clinically and treated orally with Chloroquine and Quinine. Tuberculosis is with an estimated rate of 9 cases in a population of approx. 18.000 endemic, but not epidemic. Tuberculosis is treated under a governmental programme. According to the WHO scheme daily observed treatment (DOT).
- Sexually transmitted diseases (STD) seem to be common. There are an unknown number of sex workers in Tatelu. 1 HIV positive case is known. The amount of Hepatitis B and Hepatitis C cases is unknown due to missing laboratory facilities, but Hepatitis seems to be prevalent. Gonorrhoea is common.
- The dental status of most people is very bad, as in Kalimantan.
- Due to insufficient sanitary conditions diarrhoeal diseases are very common. But it is not a major cause of mortality. Typhus outbreaks are common, many children have already had typhus. Cholera outbreaks occur too.
- Skin diseases, parasitism, and upper respiratory infectious are other important diseases in Dimembe.
- Smoking is an epidemic habit of nearly all adult men.

Children's health (Tatelu area)

The main health problems of children in Tatelu seem to be:

- High exposure to mercury in the area. Children to have access to fluid mercury, they play with his mercury with their bare hands. They live within the houses where panning or amalgam smelting is carried out, therefore they are also exposed to mercury fumes.
- A large number of children, some as young as 8 years of age, work away from their family homes. They work in the mining area. These children earn some money after school by performing various kinds of work, for example working in tunnels, carrying sacks with ore, hammering ore to pieces,

emptying ball mills, squeezing towels and searching for amalgam, even smelting is performed by these children. This is extreme child labour at very early years of life, partially physically very hard, partially related to high exposure of mercury. Accidents related to work are a health hazard for these children.

- Due to poor sanitary conditions infectious diseases like gastro-intestinal infections and malaria are very common and are a risk for children's health.
- Neonatal mortality can be estimated, in 2002 4 children died in a population of approx 200 children. After the neonatal age child death occurs only very rarely.

Hygienic and social problems (Tatelu area)

The interviews showed some other problems:

- Poor sanitary conditions are a health hazard.
- The drinking water in Tatelu and the other villages is not very safe. 90% of the people drink spring water. Many houses in Tatelu have no toilets. Proper disposal systems for waste including excrement's are missing. Waste is disposed outside the houses and burned.
- In the mining area the miners do not have access to safe drinking water, some drinking water already contains mercury. The water in the mining area should not be used for drinking purposes.
- The huts and camps in Tatelu have no toilets. Proper disposal systems of waste including excrement's are missing. Waste is just dumped.
- The former outbreaks of typhus and cholera seem a consequence of these bad hygienic standards.
- Dark fumes are emitted from the engines for power generators and ball mills, motorcycles, trucks and of burning waste. These fumes contain small particles and PIC's (products of incomplete combustion) and cause damage to the upper and lower airways
- Small scale gold mining operations are illegal. Legalisation does not seem to be of any public interest.
- Corruption is still common, and small scale miners are more vulnerable to corruption, since their work is considered illegal.
- HIV / Aids Illegal small-scale miners are mobile men with money, and they form a high risk group for spreading the virus in the community and into other areas. Shortly before the field project started, UN-AIDS asked kindly to perform a HIV test for all participants. There was no time left to change the health assessment protocol, to include all necessary investigations for AIDS. But mainly the missing treatment opportunities for HIV positive participants made it ethically impossible to carry out a HIV test in this project. In Kalimantan Dr. Robertus Pamuryanto is a part of the regional AIDS task

force and would welcome testing the participants. The AIDS / HIV topic needs to be discussed further.

3.7.2. Health Assessment – Clinical Impression

The questionnaire from the UNIDO health assessment protocol was translated in Bahasa Indonesia (see appendix). All 496 participants filled in a questionnaire with the help of the nurses. All participants were physically examined including neurological testing. Specimens (blood, urine, hair) of all participants were taken at that time. A mobile Hg analyser was used to determine total mercury in urine. Video and photo documentation was carried out.

Clinical and neurological examination – Central Kalimantan

Our clinical impression was, that a fair amount of workers from Galangan and Kereng Pangi showed severe symptoms, well related to the classical picture of mercury intoxication. They reported about fatigue, tremor, memory problems, loss of weight, metallic taste and sleeping disturbances. Intentional tremor, mainly fine tremor of eye lids, lips and fingers, severe ataxia, dysdiadochokinesia and altered tendon reflexes were observed. It should be noted that the workers from Galangan were primarily very healthy and strong young men (healthy worker effect). Participants who worked for more than 5 years in the area seemed to have more severe clinical symptoms. We might not have seen the most severe cases, since the people from the Galangan area had to come to Kereng Pangi for the examination. Due to a lack of a highly developed social system in Indonesia, some very sick workers might also have moved back to their original homes and families elsewhere in Indonesia.

The participants from Kereng Pangi, showed clinical signs of mercury intoxication, mainly if they were working in "Toko Mas", the gold shops where the amalgam is heated to extract the gold.

The children in general were fairly healthy. The nutritional status of the children was good. Many children suffered from Asthma. The children were physically very fit, and very well socialised. But some of the children showed neurological symptoms such as ataxia, that might be due to the high mercury exposure in their surrounding.

The control group in Tangkiling was fairly healthy and did not show any special health problems (53 people, mainly women).

Clinical and neurological examination – Northern Sulawesi

Some miners from the Tatelu area showed severe symptoms of the classical picture of mercury intoxication. They reported about general health being worse since working with mercury, metallic taste and salivation problems. Intentional tremor, mainly fine tremor of eye lids, lips and fingers, ataxia and dysdiadochokinesia were observed. The workers from Tatelu are primarily very healthy and strong young men (healthy worker effect). Since Tatelu is a new mining area, most miners had worked less then 5 years with mercury.

The participants from Tatelu village, that did not work with mercury, showed not many clinical signs of mercury intoxication.

The children in general were very healthy. The nutritional status of the children was good. The children were physically very fit, and very well socialised. Many of the children did work in the mining areas and had a different length of exposure to mercury.

Children with exposure to mercury already showed neurological symptoms such as ataxia or dysdiadochokinesia and light tremor.

The control group in Air Mandidi consisted of 32 children (11-12 years of age) and 21 young workers from a water company. Both control groups did not have mercury levels above HBMI. Both groups were healthy and did not show any special health problems.

Mobile Laboratory

For the first time a mobile Hg analyser was used in an UNDIO mercury health assessment project. It is possible to quantify total mercury in urine. The urine was dissolved with Hydrochloric acid. ZnCl was added, and the sample was analysed. Bottled mineral water was used as zero standard, and a mercuric nitrate as standard solution.

In nearly all cases it was possible to analyse the sample. From a clinical perspective the results are promising. All urine samples will be once more analysed in the Institute of Forensic Medicine. After that this field method can be well compared against a standard reference method.

Differences between the two field projects.

It was very challenging to perform two projects in Indonesia. Comparing the field projects, some first differences between the two projects are obvious.

In Kalimantan the local health unit took a very active part. The local doctor was very engaged and effective in mobilizing the participants, may be due to his excellent connection and acceptance in the area. The interview part of the questionnaire was performed by the local nurses (questionnaire 1-4). A problem was, that too many different nurses performed the interview. They just wanted to help, without being properly trained to do the interview.

In Sulawesi the local health unit was not a part of the examination. The examination took place in a village hall. The local head of the village promised to mobilize the participants, but was only successful with some villagers and school children, but not with miners. The miners were difficult to mobilize, direct contact between the health team and the miners was a good way to mobilize them. The interview section was performed by members of the local Department of Energy, or laboratory technicians, but not nurses. The quality of the interviews varies therefore, and we have a strong bias due to the interviewer in all the questionnaire section, The quality of the interviews is good enough to make the decision about an intoxication, but it might not be good enough to improve the quality of the health assessment.

Another problem is, that the miners are regarded as illegal miners. Just some years ago the Department of Energy collaborated in with the police to forcefully remove the miners from the mining sites in Tatelu / Sulawesi. As a result it is difficult to approach the miners with an health assessment team, that is accompanied by many uniformed officials either from the community or the Department of Energy. Mainly in Sulawesi the miners mistrusted the health assessment, even more since they "were examined for free, and even received a small per diem, instead of paying the doctor". In future projects, the health assessment should be strongly connected to the local health unit, and all other officials, should remain more in the background.

The language barrier was enormous, since hardly anybody in the mining areas speaks or understands English. In Kalimantan we had one interpreter, but in Sulawesi the pre-selected interpreter herself admitted having only passive English language knowledge. In Kalimantan part of the participants where Dayaks, and some of them did not understand Bahasa Indonesia, but only their local dialect. Since the health assessment depends a lot on communication between the expert team and the participants, for future projects the interpreter question has to be handled by UNIDO with more care. A careful training of a few, well selected nurses and interpreters is necessary in the first few days.

The support from Mansur Geiger, from P.T Kalimantan Surya Kencana, and his enormous knowledge of the area was very helpful. In Sulawesi we did not experience such an expert advice.

3.7.3. Description of mercury levels in urine, blood and hair

In Table 13 the total mercury concentrations of all analysed blood, urine and hair samples are summarised. In all blood samples the mercury concentration was above the detection limit of 0.20 µg/L. In 6 urine samples the mercury concentration was below the detection limit of 0.20 µg/L. For statistical purposes, in these cases the value was set to ½ of the detection limit (0.10 µg/L). In all hair samples the content of total mercury was above the detection limit (0.02 µg/g). In 467 cases the concentration of inorganic mercury in hair was above the detection limit of 0.04 µg/g. In these cases the concentration of organic bound mercury could be calculated by the difference total Hg minus inorganic Hg (Table 14).

Table 13 - Concentration of total mercury in blood, urine and hair

		This project	For comparison	
		Indonesia	Philippines (gold mining area)	Germany
Hg-blood (µg/l)	case number	491	323	3958
	span	1.45 – 429	< 0.25 – 107.6	< 0.2 – 12.2
	median	8.4	8.2	0.6
	arithmetic. mean	16.6	11.48	0.51
	literature		(Drasch 2001)	(Krause 1996)
Hg-urine (µg/l)	case number	492	313	4002
	span	< 0.20 – 5 240	< 0.25 – 294	< 0.2 – 53.9
	median	4.6	2.5	0.5
	arithmetic. mean	40.47	11.08	1.11
	literature		(Drasch 2001)	(Krause 1996)
Hg-urine (µg/g creatinine)	case number	492	313	4002
	span	< 0.20 – 1 697	< 0.1 – 196.3	< 0.1 – 73.5
	median	2.7	2.4	0.4
	arithmetic. mean	17.99	8.40	0.71
	literature		(Drasch 2001)	(Krause 1996)
Total Hg-hair (µg/g)	case number	488	316	150
	span	0.33 - 792	0.03 – 37.76	0.04 – 2.53
	median	2.64	2.72	0.25
	arithmetic. mean	9.15	4.14	
	literature		(Drasch 2001)	(Drasch 1998)

Table 14 - Concentration of organic mercury in hair

		Indonesia (this project)	Tanzania
Organic Hg-hair (µg/g)	case number	467	123
	span	< 0.10 - 326	0.10 – 5.25
	median	1.74	0.44
	arithmetic. mean	3.98	0.62

For comparison the results of a recent project in a small scale gold mining area of the Philippines (Drasch 2001) are reported in the same Table 13; further, for blood and urine, the result of a representative epidemiological study, performed 1990/92 in Germany, an industrial country in Western

Europe (Krause 1996). For a better comparison of the (total) hair values, recently published own data from Germany are cited (Drasch 1998). The organic bound Hg in hair (Table 14) was compared to a similar project, just finished in Tanzania (Drasch 2004b).

In recent literature from Europe and Northern America similar Hg concentrations in blood, urine and hair have been reported (Drasch 2004a). From populations with a high consumption of methyl-mercury-contaminated sea food like in Japan, the Faeroes Islands, the Seychelles or Canadian Inuit higher Hg values in the bio-monitors have been reported recently e.g. on the International Conferences on “Mercury as a Global Pollutant” 1996 in Hamburg, Germany, 1999 in Rio de Janeiro, Brazil and 2002 in Minamata, Japan (for literature in detail see proceedings). From other areas with small scale gold mining like in the Amazon, Brazil, mercury concentrations, comparable to the found levels, have been reported e.g. at these congresses or summarised in the book “Mercury from Gold and Silver Mining: A Chemical Time Bomb?” by de Lacerda and Salomons (1998).

All mercury concentrations in the different bio-monitors blood, urine and hair are highly significant rank correlated (table 3 and 4 in appendix 1). Despite this, the individual values scatter widely (see Figures 3-8a).

Exclusion of data

From the total group 23 cases were excluded from further statistical analysis:

- 16 seniors older than 59 years
- 7 participants with severe neurological diseases.

Their age or disease might have biased the result of their neurological investigations and/or their neuro-psychological tests.

Nevertheless, for these 23 cases the decision about an individual diagnosis of mercury intoxication (see below) was made as well .

Forming subgroups due to residence and occupation

To distinguish between the possible sources of mercury burden, we formed subgroups. The remaining 469 participants (222 from Sulawesi, 247 from Kalimantan) were subdivided due to residence and occupation criteria. The following subgroups were formed (Table 15).

Table 15 - Number of participants per sub-group

	Sulawesi	Kalimantan
Control adults	22	36
Former miner (in control area)	0	10
Not occupational burdened	18	67
Mineral processors	17	30
Amalgam-burners	61	69
Control children	31	0
Children not working with Hg	22	27
Children working with Hg	51	8
Sum	222	247

A) Sulawesi

- Control group adults: 22 adults from Air Mandidi, without known special Hg burden.
- Not occupational burdened: 18 adults living in the mining area of Tatelu without any special occupational Hg-burden.
- Mineral processors: 17 adult mineral processors, living in the mining area of Tatelu.
- Amalgam-burners: 61 adults, amalgam-burners living in the mining area of Tatelu.
- Control group children: 31 children from Air Mandidi without special Hg burden.
- Children not Hg work: 22 children living in the mining area of Tatelu without any special occupational Hg-burden.
- Children working with Hg: 51 children living in the mining area of Tatelu, working with mercury.

B) Kalimantan

- Control group adults: 36 adults from Tangkiling without known special Hg burden.
- Former miners: 10 adults, former miners, now living in the control area of Tangkiling.
- Not occupational burdened: 67 adults living in the mining area of Galangan without any special occupational Hg-burden.
- Mineral processors: 30 adult mineral processors living in the mining area of Galangan.

- Amalgam-burners: 69 adults, amalgam-burners, living in the mining area of Galangan.
- Children not Hg work: 27 children living in the mining area of Galangan without any special occupational Hg-burden.
- Children working with Hg: 8 children living in the mining area of Galangan, working with mercury.

Unless otherwise indicated, all further statistical analysis was performed with these subgroups.

In Figures 38 and 39 the age distribution of all sub-groups is displayed. As expected, there is a surplus of males in the occupational burdened groups (amalgam-burners and former occupational burdened volunteers) (tables 6 and 7 in appendix 1). This gender difference could not be controlled in field under the given conditions.

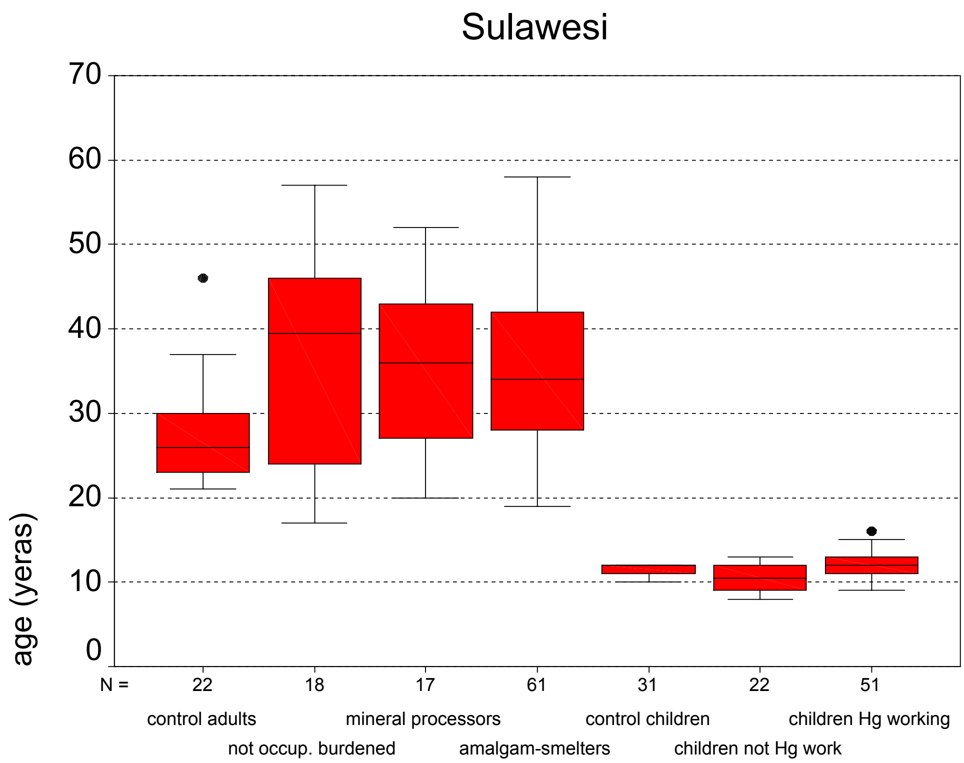


Figure 38 - Age distribution of all volunteers from Sulawesi, selected for the statistical evaluation

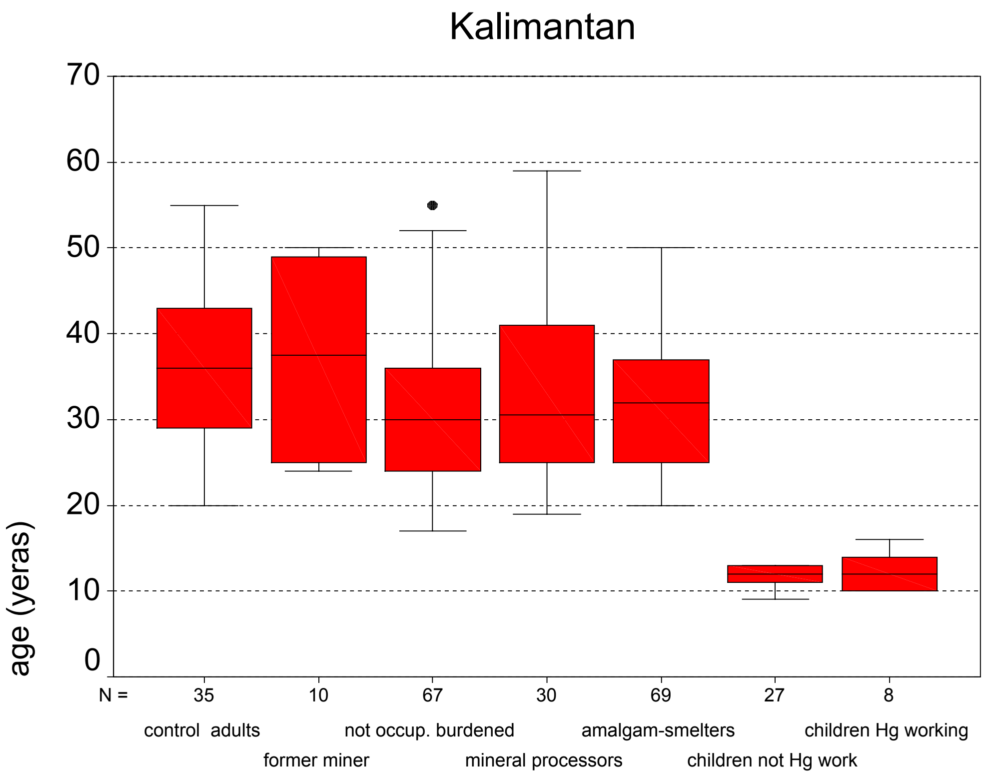
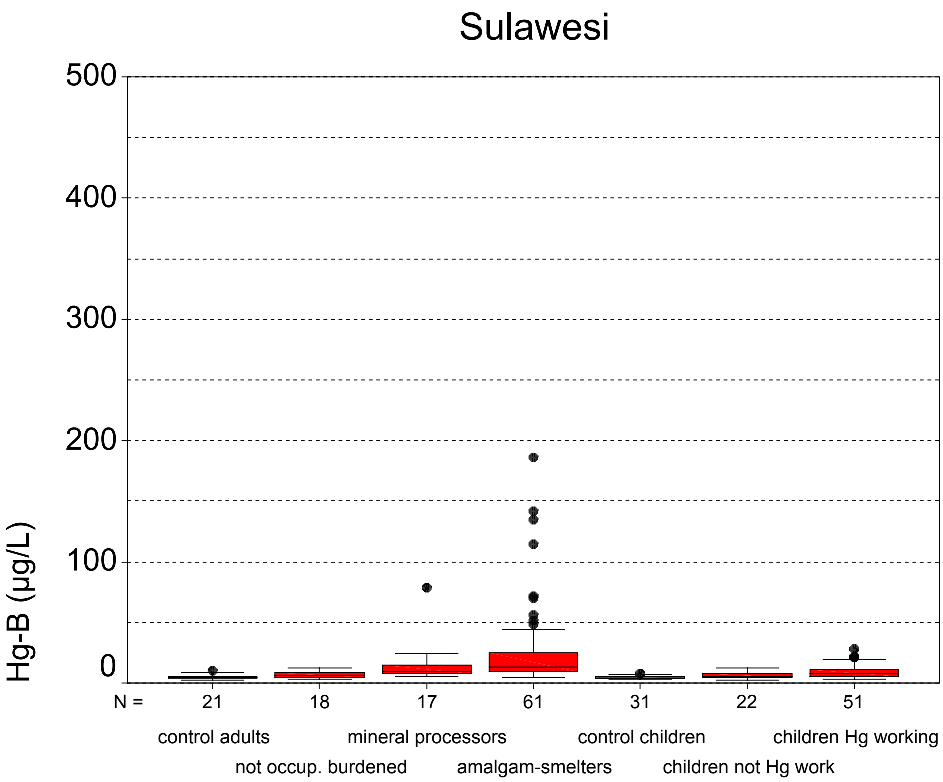


Figure 39 - Age distribution of all volunteers from Kalimantan, selected for the statistical evaluation

3.7.4. Statistical analysis of mercury levels in urine, blood and hair

Statistical testing of the different Hg-burdened subgroups versus mercury concentration in blood, urine and hair show significant results **(tables 6 to 8 in appendix 1),** Figures 40 to 45a**.**



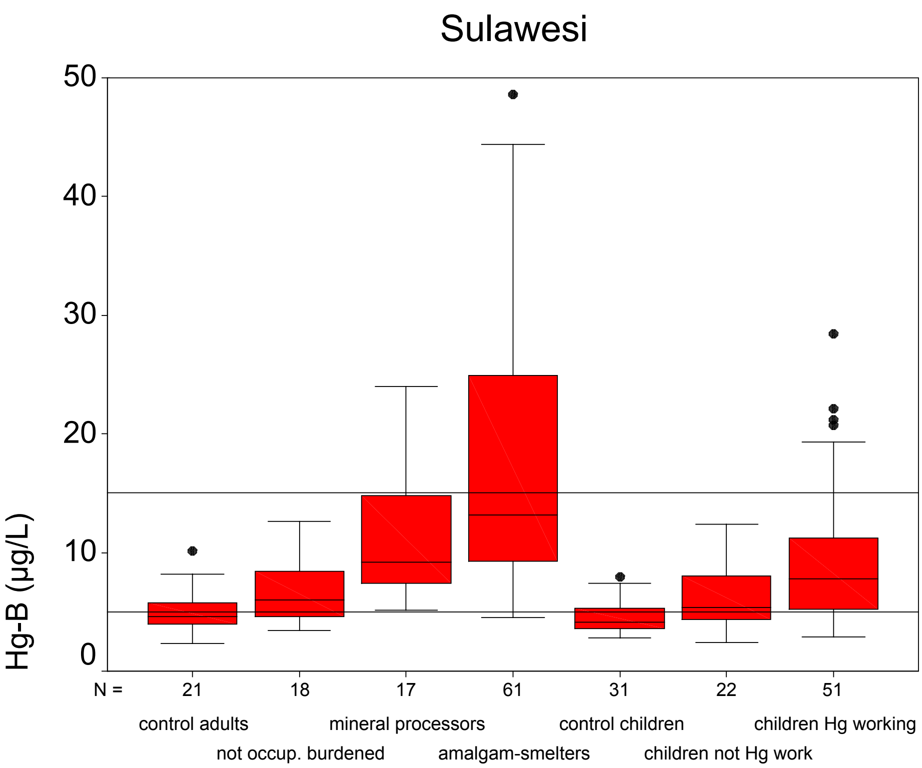
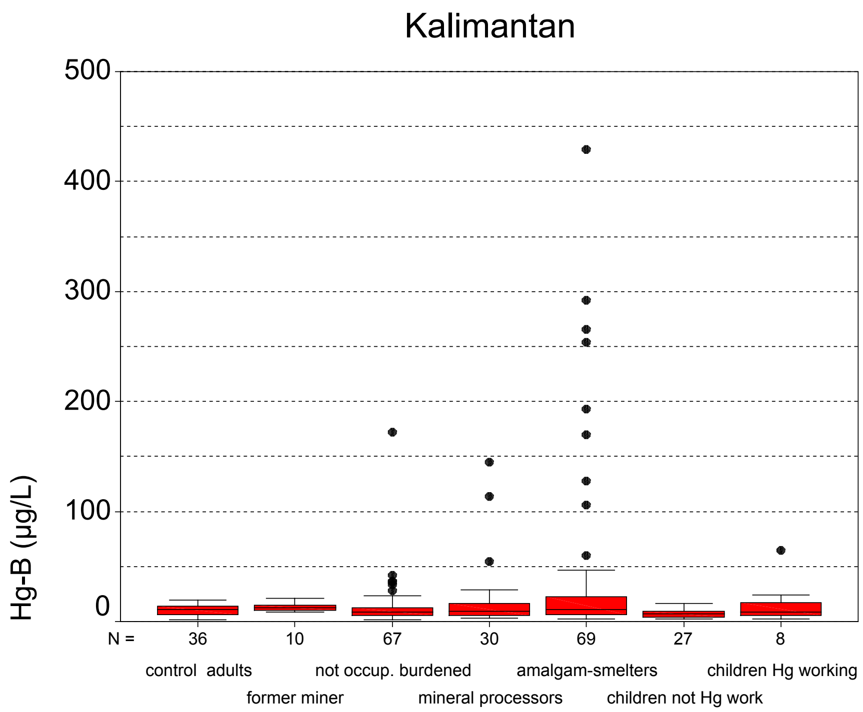


Figure 40 and 40a (expanded y-axis) - (Total) mercury concentration in blood samples from Sulawesi



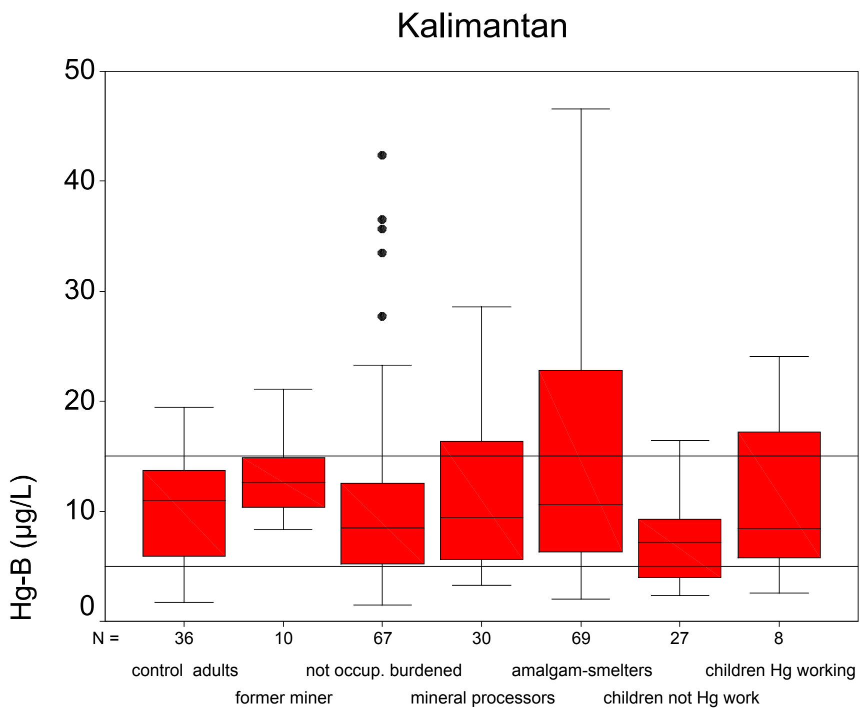
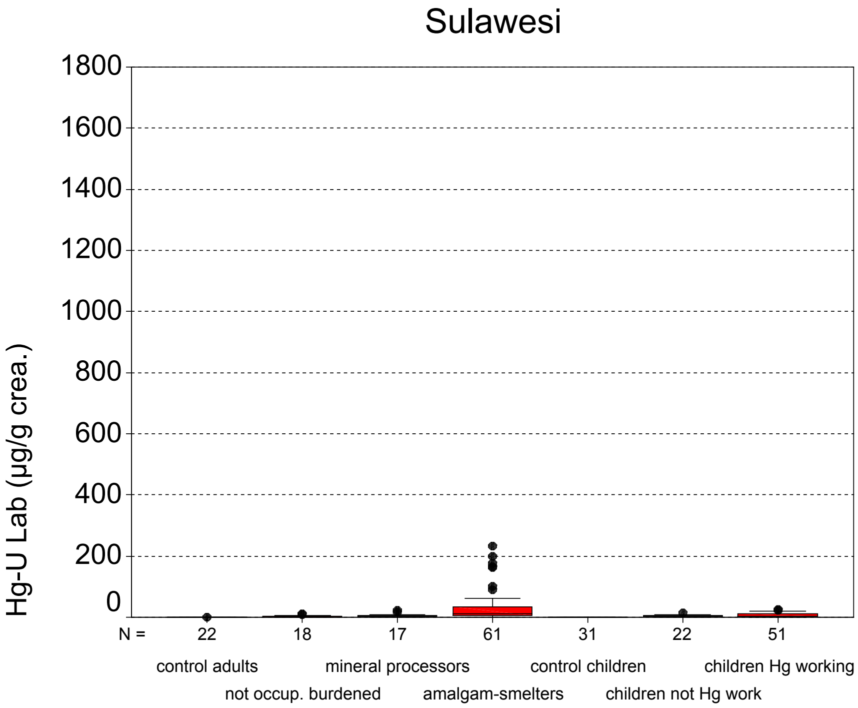


Figure 41 and 41a (expanded y-axis) - (Total) mercury concentration in blood samples from Kalimantan



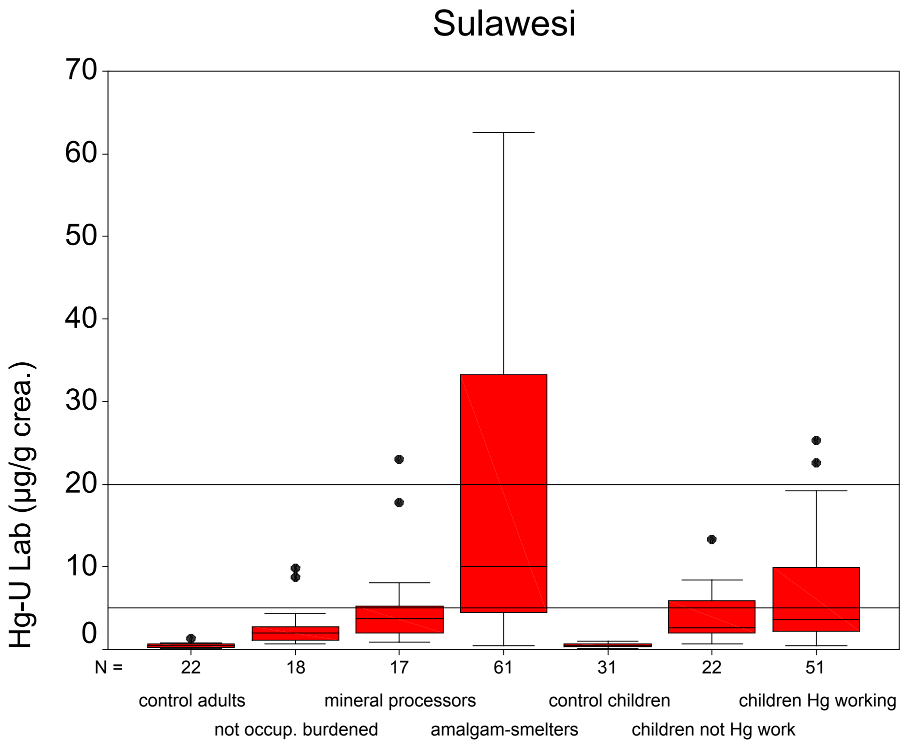
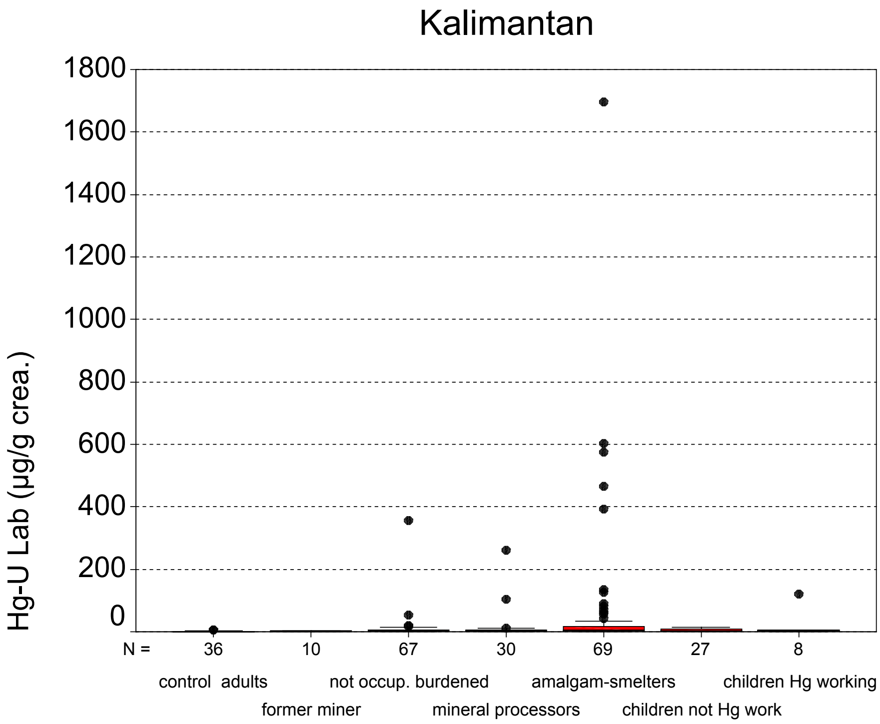


Figure 42 and 42a (expanded y-axis) - (Total) mercury concentration in urine samples from Sulawesi



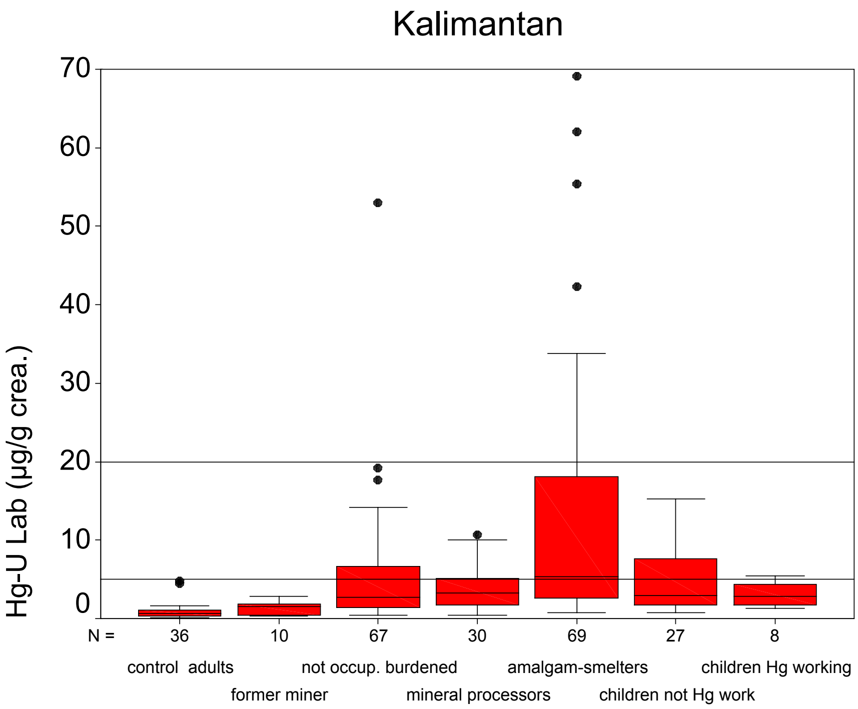


Figure 43 and 43a (expanded y-axis) - (Total) mercury concentration in urine samples from Kalimantan

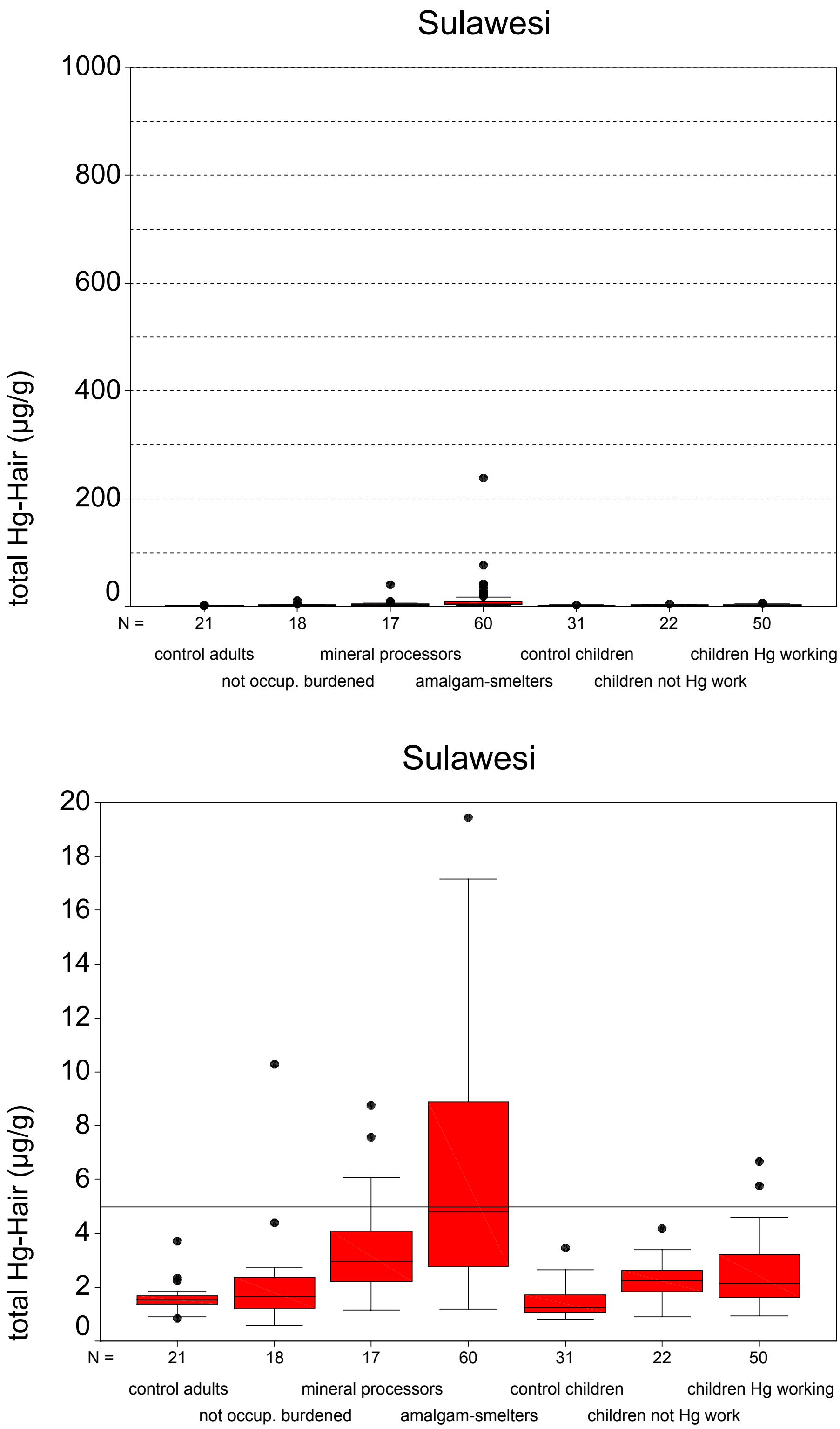
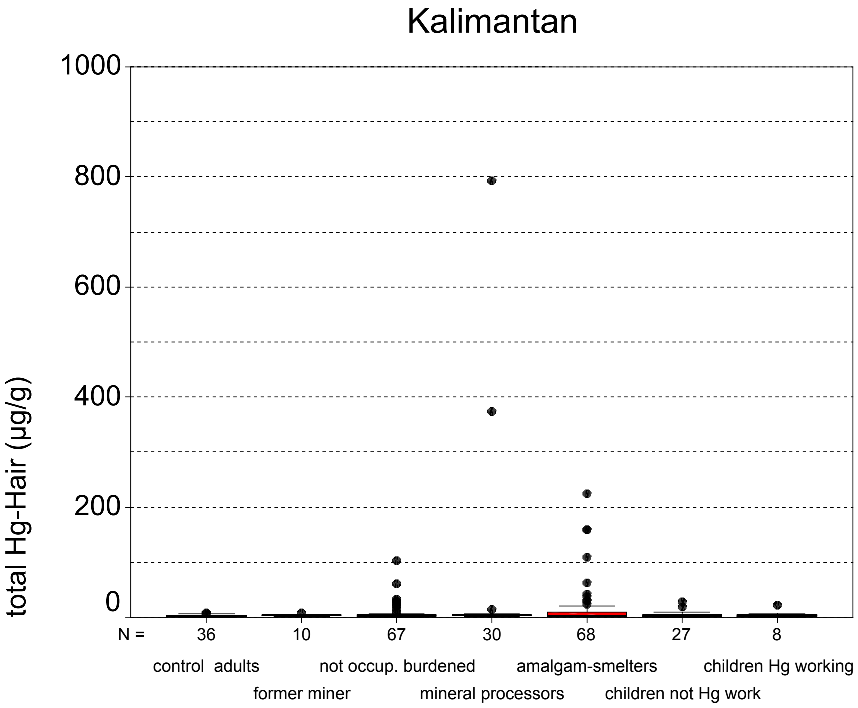


Figure 44 and 44a (expanded y-axis) - Total mercury concentration in hair samples from Sulawesi.



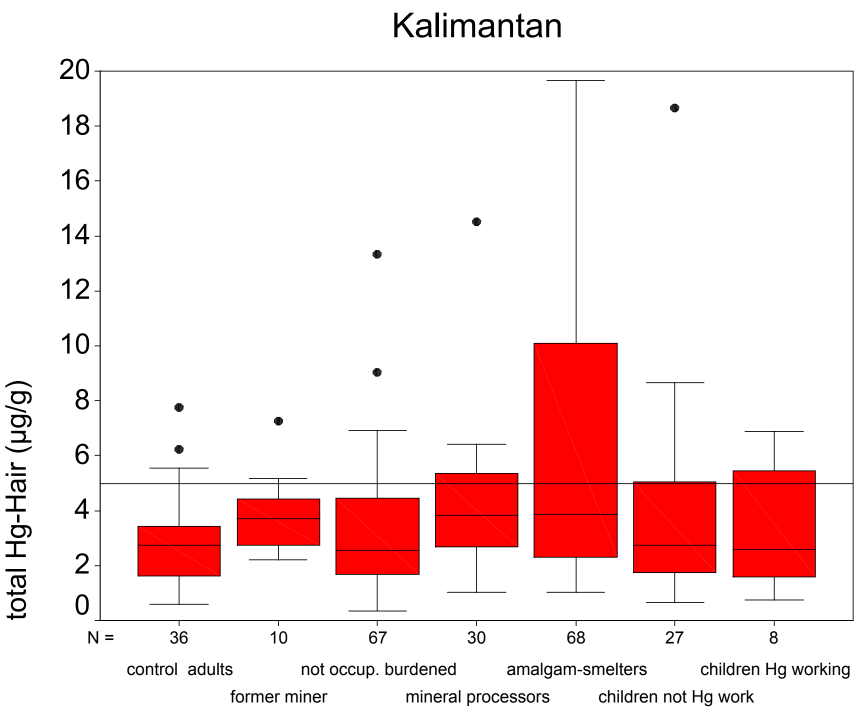


Figure 45 and 45a (expanded y-axis) - Total mercury concentration in hair samples from Kalimantan

3.7.5. Control Groups

The mercury concentration in the blood, urine or hair of the Sulawesi control group is in the same order of magnitude as in non-burdened populations in Western Europe (see Table 15), Figure 46. In contrast to this, the mercury concentration in blood and hair of the "control group" in Kalimantan is markedly higher (Figures 41a and 45a). Moreover it must be taken into consideration that this highly burdened population in Central Kalimantan live far from the coast, whilst the low burdened Sulawesi control group is a coastal population. High mercury concentrations in blood and hair, moderate in urine (Figure 43a) and a ratio of approximately 9:1 between organic and inorganic mercury in hair (see Figure 10) indicate a burden by methyl-mercury.

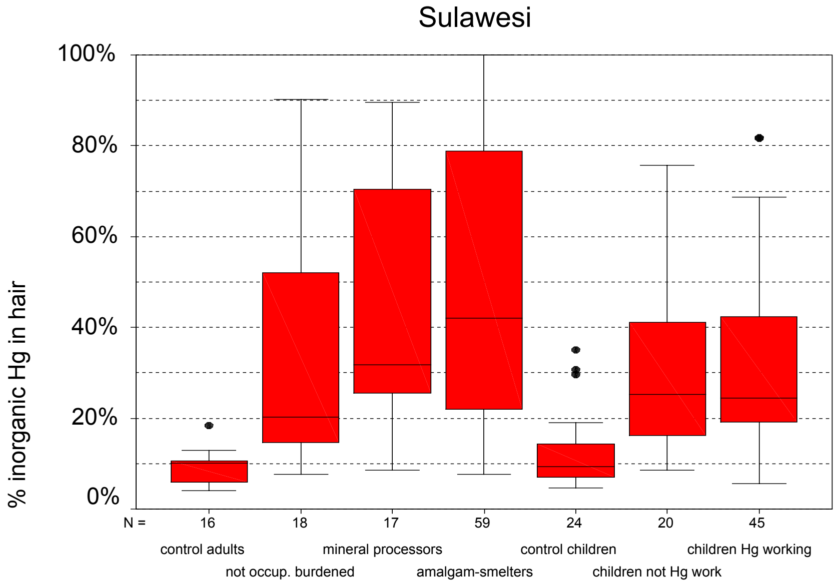


Figure 46 - Percentage of inorganic mercury in hair samples from Sulawesi

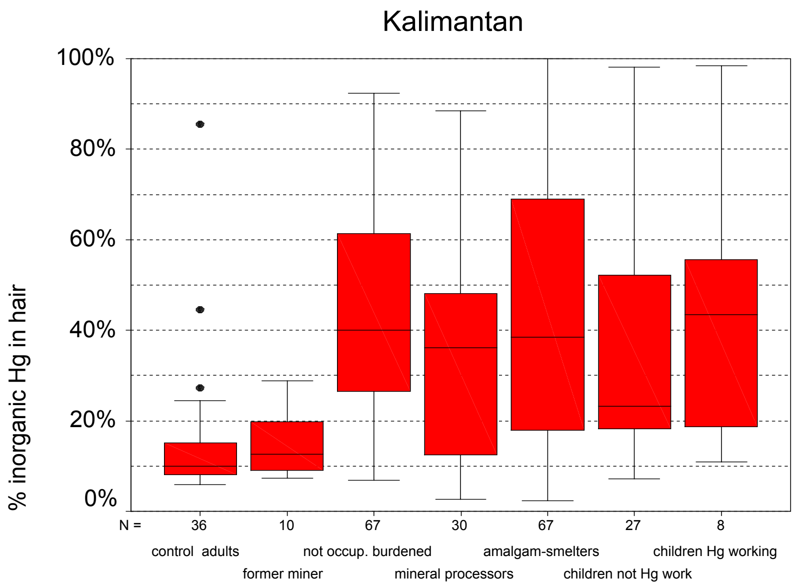


Figure 47 - Percentage of inorganic mercury in hair samples from Kalimantan

Figure 48 shows the dependence of the mercury concentration found in the blood of this population to the frequency of fish consumption. For mercury in hair, the dependence is comparable (not shown). This results in the assumption that there must be a local source of mercury which contaminates the river. In the aquatic food chain this primarily inorganic mercury is methylated and accumulates in this even higher toxic form in fish. Our team acknowledged indications of further gold mining activities upstream from Tangkiling. These mining activities are usually illegal, and new mining activities are frequent (gold-rush area). Whatever the reason may be for the increased burden in this area, the region can not qualify asan unpolluted "control area". Moreover, the population from Tangkiling showed more frequent neurological deficiencies than e.g. the control group from Air Mandidi on Sulawesi (**see table 7 in appendix 1**). Therefore it was decided to compare all burdened groups to the control group from Sulawesi and to interpret the population from Tangkiling as a further burdened group.

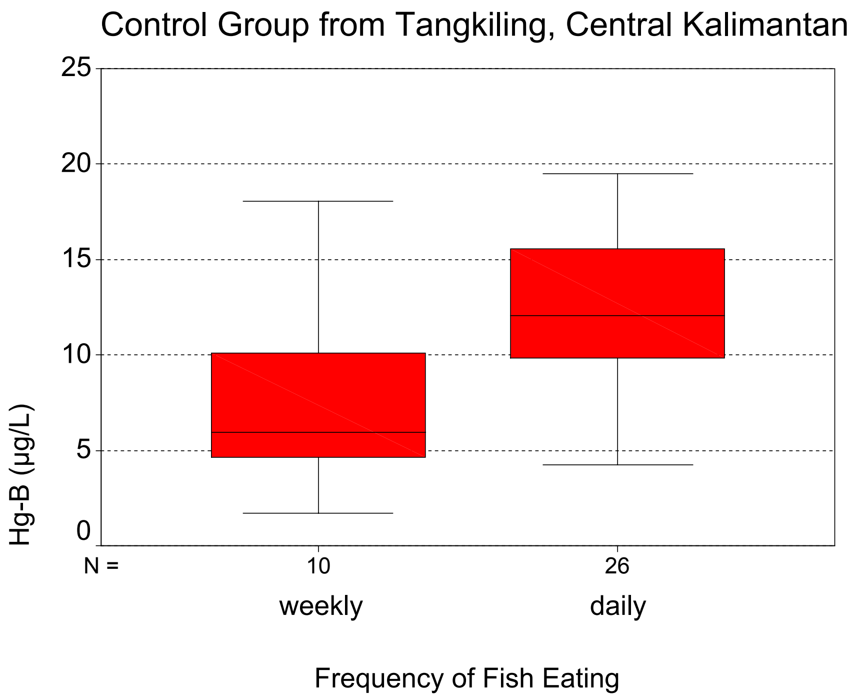


Figure 48 - Dependence of the mercury concentration found in the blood of the Tangkiling "control group" , Central Kalimantan to the frequency of fish consumption

As known from literature (Drasch 2004a) and recent experiences in other gold mining areas such as the Philippines (Drasch 2001), an increased methyl mercury burden from food results in increased mercury concentrations in blood and hair, but not, or just moderate elevated mercury levels, in urine. This explains why it was not possible for us to detect the methyl mercury burden in Tangkiling by our urine screening on field. This situation underlines the necessity to analyse not only urine samples but urine <u>and</u> blood and/or hair for mercury to pin-point populations possibly burdened by methyl-mercury. It must be stressed that similar problems could occur with populations living downstream from other gold mining areas.

3.7.6. Burdened Groups

As expected, the highest mercury concentration was found in the bio-monitors of the Hg-occupational burdened group of amalgam-burners, followed by other inhabitants of the gold mining areas (see Figures 40 to 45a and **tables 6 to 8 in appendix 1**). The mercury blood concentrations of the burdened groups in Kalimantan and Sulawesi are comparable, the mean Hg urine concentrations also. But there are some extreme high single Hg urine values in Kalimantan of up to almost 1.700 µg/g creatinine, in contrast to peak levels of "just" 230 µg/g creatinine in Sulawesi. For hair the situation is similar: Comparable mean mercury values in Kalimantan and Sulawesi but extreme high top concentrations in Kalimantan - up to an almost unbelievable 800 µg/g. Perhaps these extreme hair values result from an external contamination by mercury vapour, but the extreme high urine and the high blood concentrations cannot be explained by a contamination. In combination with the high percentage of inorganic mercury in hair (see Figures 46 and 47) they indicate a massive burden with mercury vapour (and inorganic mercury) as in the two gold mining areas of Tatelu in Sulawesi and Galangan in Kalimantan.

Some few cases, all from Galangan in Kalimantan, showed extreme high mercury concentrations in blood and extreme high concentrations of organic bound mercury in hair (Table 16). This may be explained by fishing in heavily mercury contaminated pit holes in this mining area, as observed by our team.

Table 16 - Cases with extreme high concentrations of organic Hg in hair and (total) Hg in blood.

Case number	Hg-U (µg/g creatinine)	Hg-B (µg/L)	total Hg-Hair (µg/g)	inorganic Hg-Hair (µg/g)	organic Hg-Hair (µg/g)	% organic Hg in Hair
1	104	114	792	466	326	41,2 %
2	262	145	373	180	1943	51,9 %
3	55	292	158	75	83	52,6 %
4	604	254	62	32	30	48,5 %
5	128	106	42	20	22	53,1 %

3.7.7. Mercury Levels compared to Toxicological Threshold Limits

In the international literature only a few threshold limits for mercury in bio-monitors are recommended. Especially for the exposure to metallic mercury vapour there is not much data on threshold values available. This metallic mercury vapour is the main exposure in small scale gold mining areas (Drasch

2004a). Most studies in this field are performed in populations with an exclusively methyl-mercury burden from fish or sea-food, such as the former data from Minamata, or the more recent data from the Seychelles (Davidson 1998), the Faeroes Islands (Grandjean 1997) or even from the Amazon (Grandjean 1999). To estimate the toxicological relevance of the burden with predominantly mercury vapour of the investigated population from Tatelu in Sulawesi and Galangan in Kalimantan, the following threshold limits were used.

German human-bio-monitoring (HBM) values for mercury

In 1999 the German Environmental Agency ("Umweltbundesamt") published recommendations for human-bio-monitoring-values (HBM) for mercury ("Kommission Human-Biomonitoring" 1999).

The HBM I was set to be a "check value", this means an elevated mercury concentration in blood or urine, above which the source of the Hg-burden should be searched and, as far as possible, eliminated. But even by an exceeding of this HBM I the authors claimed that a health risk is not to be expected.

In contrast to this, the (higher) HBM II value is an "intervention value". This means, at blood or urine levels above HBM II, especially over a longer period of time, adverse health effects cannot be excluded. Therefore interventions are necessary. On the one hand the source should be found and reduced urgently. On the other hand a medical check for possible symptoms should be performed. For hair, comparable values are not established, but the HBM II in blood is directly derived from the assumption of a stable ratio of mercury in blood and hair (1:300) and the result of the Seychelles study, where adverse effects could be seen at a mercury concentration in hair above 5 µg/g (Davidson 1998). Therefore this value was taken in our project as an analogous value for HBM II for the toxicological evaluation of mercury concentration determined in hair. It must be kept in mind, that this threshold limit in hair was established in a population burdened with methyl-mercury from marine food and not with mercury vapour, as, with some exceptions, is predominant in the gold mining areas in Indonesia, investigated in this project.

In 1991 the WHO expert group stated that mercury in urine is the best indicator for a burden with inorganic mercury. The maximum acceptable concentration of mercury in urine was set to 50 µg/l (WHO 1991). A distinct threshold for mercury in blood was not given. Mercury in hair is widely accepted as best indicator for the assessment of contamination in populations exposed to methyl-mercury (de Lacerda 1998). For this, a maximum allowable concentration of 7.0 µg/g hair was set by the FAO/WHO. In 1997 the US EPA calculated the "benchmark limit" for total Hg in hair to 1 µg/g. This benchmark was derived from a burden with methyl-mercury from seafood and not with mercury vapour. US EPA has set a threshold limit for mercury vapour in the ambient air, but not in bio-monitors (US EPA 1997).

All these limits and others, former published, are respected at the most recent recommendation from the German Environmental Agency 1999, as cited above. The high numbers of recently published investigations on mercury burdened populations from gold mining areas such as South-America or by sea food as on the Faeroes Islands or the Seychelles require a continuous re-evaluation of toxicologically defined threshold limits. Therefore the international latest recommendation from the German Environmental Agency was taken for further comparison. This was committed with UNIDO for the total global programme, to obtain comparable results (Veiga 2003).

Occupational threshold limits (BAT, BEI)

Other toxicologically founded limits are occupational threshold limits. Such limits are established for mercury e.g. in the USA (biological exposure indices BEIs of the American Conference of Governmental Industrial Hygienists) or Germany (BAT value, Deutsche Forschungsgemeinschaft (German Scientific Community) 1999). For a better comparison with the HBM-values (which are, to our knowledge, only established in Germany) the German BAT-values for metallic and inorganic mercury are taken for this project. From definition, these BAT-values are exclusively valid for healthy adult workers under occupational medical control. The occupational burden must be stopped, if this threshold is exceeded. These occupational threshold limits are not valid for the total population, especially not for risk groups like children, pregnant women, and older or ill persons. Nevertheless, the BAT-values were also taken for a further classifying of our highest results. BAT-values for mercury are established only for blood and urine, but not for hair.

Table 16 gives an overview of the HBM-, BAT- and BEI-values. In the tables 6-8 in appendix 1, the percentage of the exceeding of the HBM II- and BAT-limits in the various population groups of our project is summarised.

Table 16 - Toxicologically established threshold limits for mercury in blood, urine and hair (HBM = Human Bio-Monitoring; BAT = "Biologischer Arbeitsstoff-Toleranzwert" (biological work-exposure tolerance limit); BEI = Biological Exposure Indices)

	Hg-blood (µg/l)	Hg-urine (µg/l)	Hg-urine (µg/g creatinine)	Hg-hair (µg/g)
HBM I	5	7	5	
HBM II	15	25	20	5 (in analogy)
US EPA bench mark				1
WHO		50		7
BAT for metallic and inorganic Hg	25	100		
BAT for organic Hg	100			
BEI (Biological exposure index)	15 (after working)		35 (before working)	

As shown in the next chapters the biological threshold limits should not be overestimated for the diagnosis. Therefore the question, which of the limits is best for evaluating the results of this project is only of secondary interest.

Reducing of redundant data for statistical analysis

From the very large data volume (see appendix 2), collected on field by the medical team, the most relevant facts and test results were selected by pre-investigations (**see tables 6 to 8 in appendix 1**). Many test results were primarily scored (for instance: no, moderate, strong, extreme). For the anamnestic and clinical data these results could be reduced to a yes/no decision, which enables a statistical analysis and facilitates the readability of the **tables 6 to 8, appendix 1** markedly without a relevant loss of information. The neuro-psychological data (memory, match-box, Frostig, pencil tapping) was reduced according to a box-plot procedure. With this procedure the results of the participants could be divided into three categories: The best performing 25% of participants of each group were given a score of 0 points, the worst performing 25% of participants were given a score of 2 points and the middle group of participants received a score of 1 point. In the **tables 6 and 7.appendix 1**, the results of the statistical analysis of the transformed anamnestic, clinical and neurological data versus the different Hg-burdened subgroups, is shown. The significance of the differences was calculated with Chi-square test. Grey marked fields contain results, differing from the control group on a statistical significant level ($p < 0.05$, one-tailed).

In Figure 50 one anamnestic criteria (“health situation worsened since mercury exposed”) is shown for adults from Sulawesi. In the Figures 51 to 54 two objective (dysdiadochokinesia, ataxia of gait) criteria, typical for a chronic mercury burden are Figured graphically. In Figure 55 the grouped results of the matchbox test, a neuro-psychological test, for the children is shown. (For a quick explanation: In this test matches have to be sorted in a box as quick as possible).

It is striking that in comparison to the control groups, many test results even from the non occupationally Hg-burdened population, living in the burdened areas are considerably worse. The negative results increase even more in the occupational Hg-burdened group of amalgam-burners. The results of the former occupational burdened group from Kalimantan should not be over-interpreted, due to the low case number (10) and the missing homogeneity of this group.

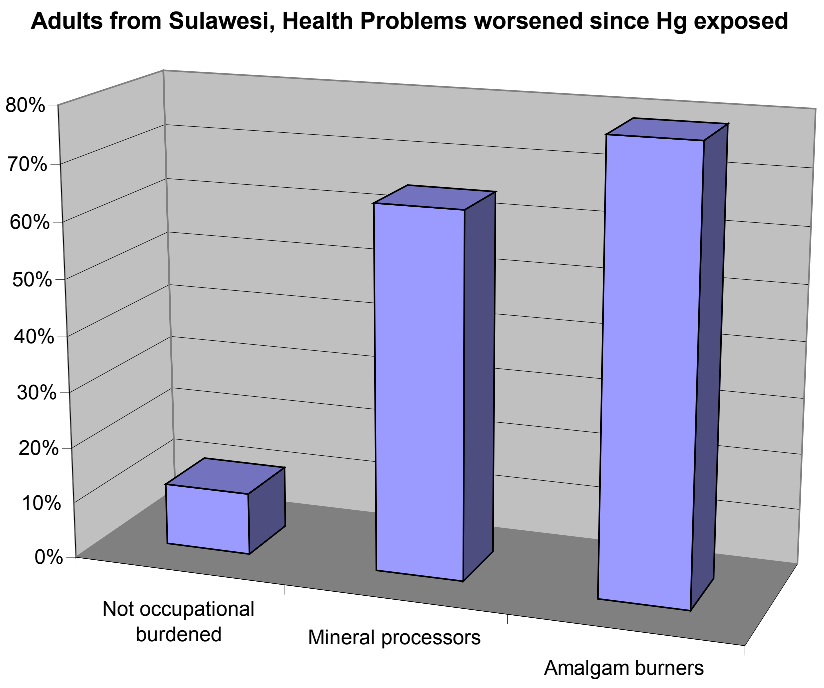


Figure 50 - Adults from Sulawesi, frequency of the anamnestic parameter "health problems" worsened since mercury exposed

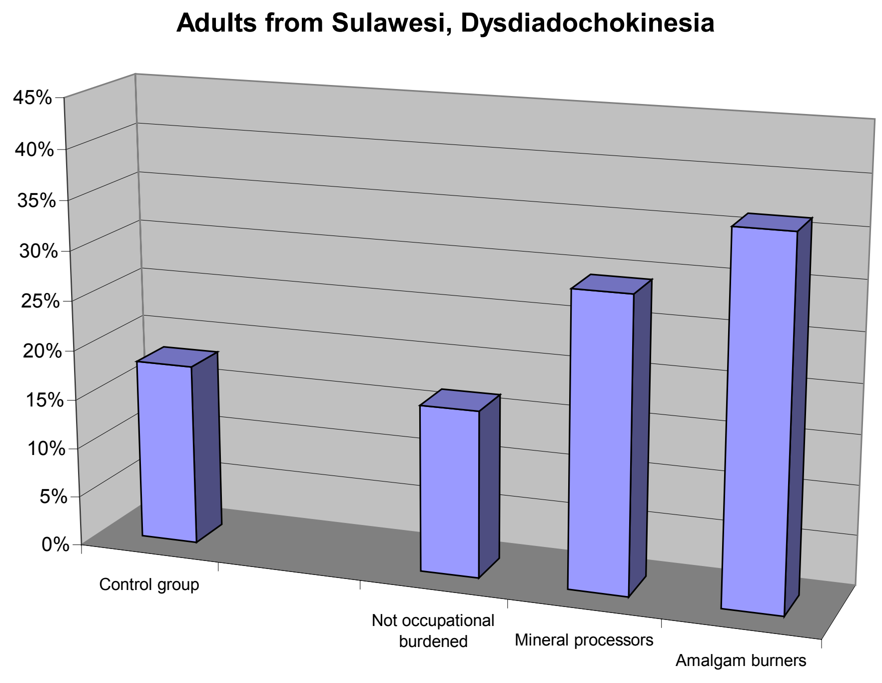


Figure 51 - Adults from Sulawesi, frequency of the clinical parameter "dysdiadochokinesia"

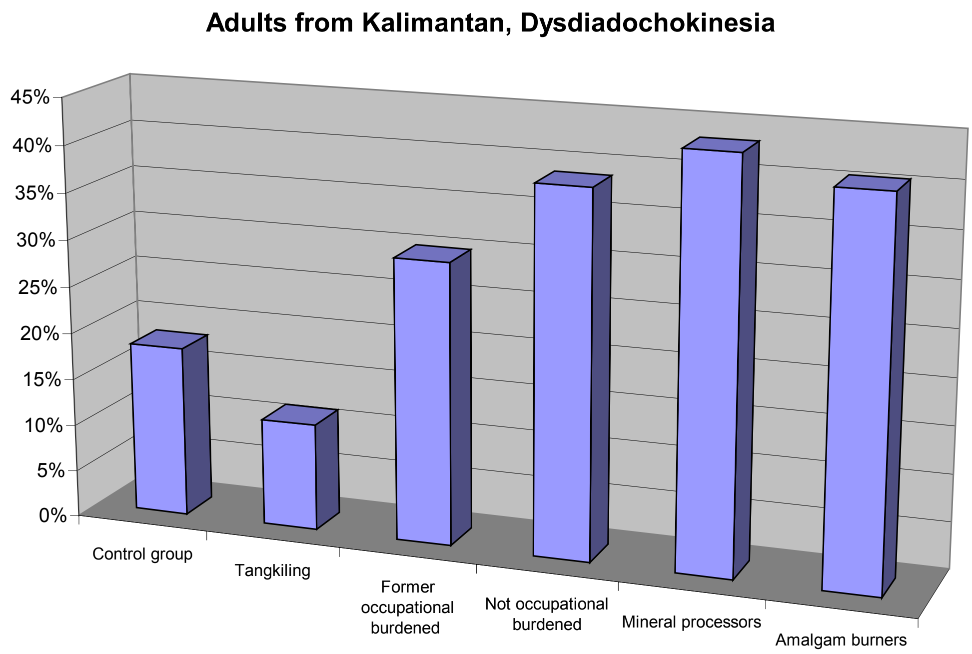


Figure 52- Adults from Kalimantan, frequency of the clinical parameter "dysdiadochokinesia"

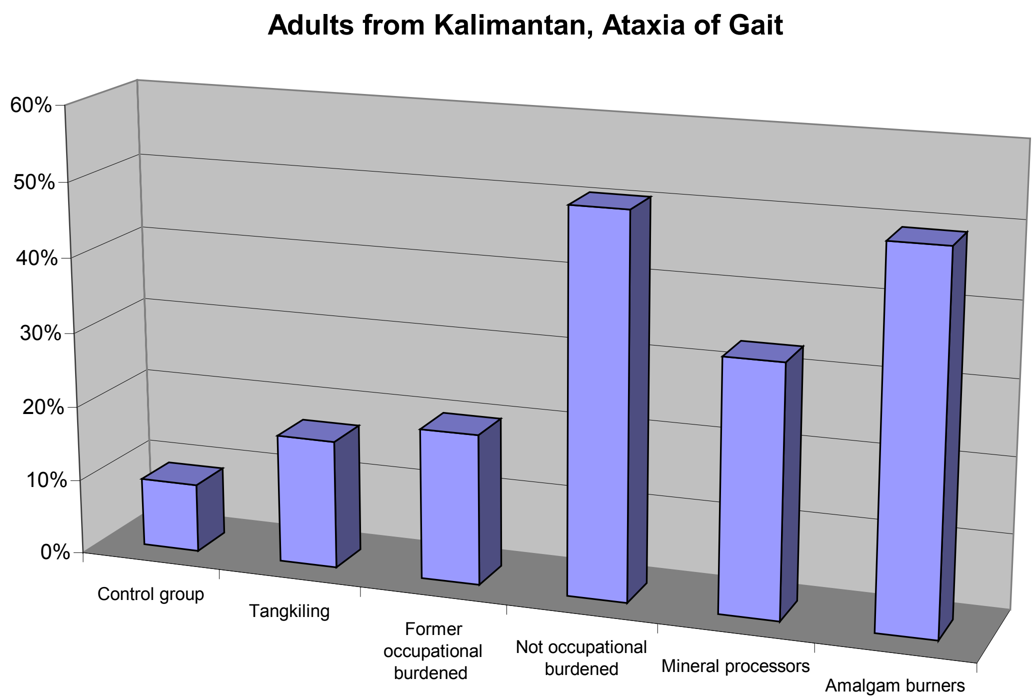


Figure 53 - Adults from Kalimantan, frequency of the clinical parameter "ataxia of gait"

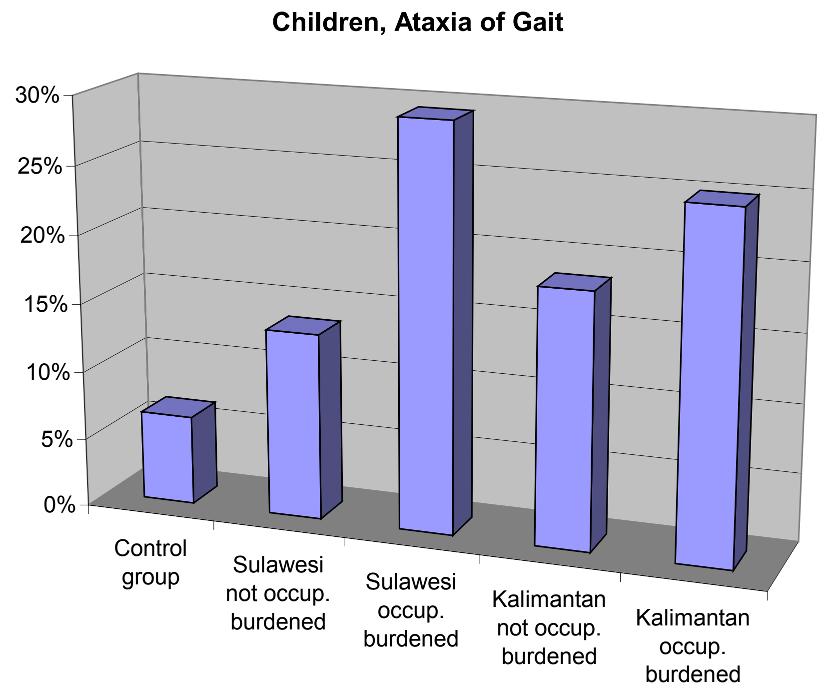


Figure 54 - Children, frequency of the clinical parameter "ataxia of gait"

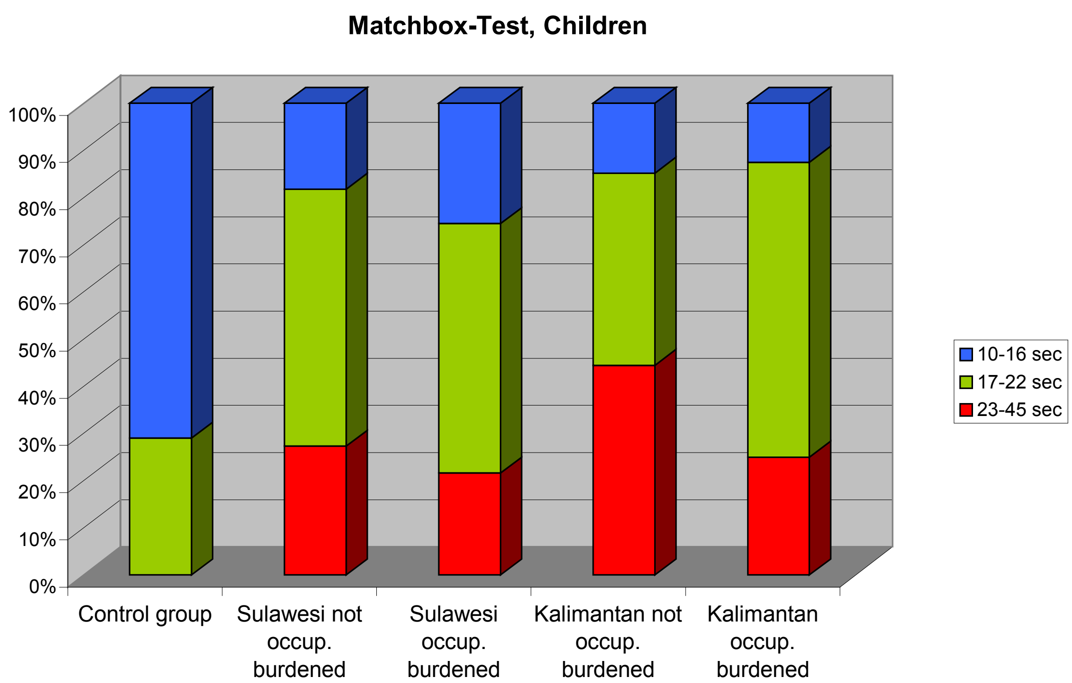


Figure 55 - Children, Matchbox test, grouped (blue is good, green is middle, red is bad)

3.7.8. Scoring of medical results

The evaluation so far showed statistically significant medical test results versus the different Hg-burdened subgroups. These significant medical test results are typical clinical signs of chronic mercury intoxication, such as tremor, metallic taste, excessive salivation, sleeping problems, memory disturbances, and proteinuria (Drasch 1994, Kommission Human-Biomonitoring 1999, Wilhelm 2000, Drasch 2004a). Furthermore ataxia, dysdiadochokinesia, pathological reflexes, coordination problems and concentration problems are clinical signs of a damaged central and peripheral nervous system. For a further evaluation of these medical results a medical score was established. The factors, included in this medical score and the score-points per factor are shown in Table 17. This score was developed from the results of a mercury burdened group in a gold mining area in the Philippines (Drasch 2001) and adopted by UNIDO, to get comparable results (Veiga 2003). The higher the total score relates to the increase of the poor health situation of each participant is.

Table 17 - Anamnestic, clinical, neurological and neuro-psychological scoring scale

Test	Score Points
Anamnestic data	
Metallic taste	0/1
Excessive salivation	0/1
Tremor at work	0/1
Sleeping problems at night	0/1
Health problems worsened since Hg exposed	0/1
Clinical data	
Bluish coloration of gingiva	0/1
Ataxia of gait	0/1
Finger to nose tremor	0/1
Dysdiadochokinesia	0/1
Heel to knee ataxia	0/1
Heel to knee tremor	0/1
Mento-labial-reflex	0/1
Proteinuria	0/1
Neuro-psychological tests	
Memory test	0/1/2
Matchbox test	0/1/2
Frostig test	0/1/2
Pencil tapping test	0/1/2
Maximum	21

Statistic testing of the different Hg-burdened subgroups versus the total medical score sum showed once again significant results. The results are shown in the **tables 6 to 8, appendix 1** and in the Figures 56 and 57 graphically as a box-plot. In Sulawesi as in Kalimantan, the mean scores of all other groups are higher (= worse) than the control groups.

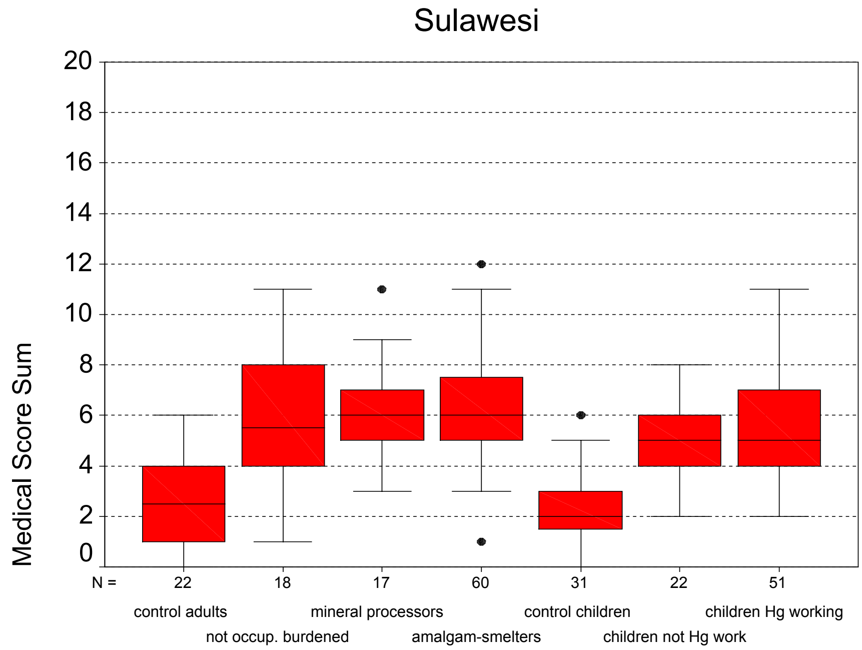


Figure 56 - Medical score sum of different sub-groups in Sulawesi

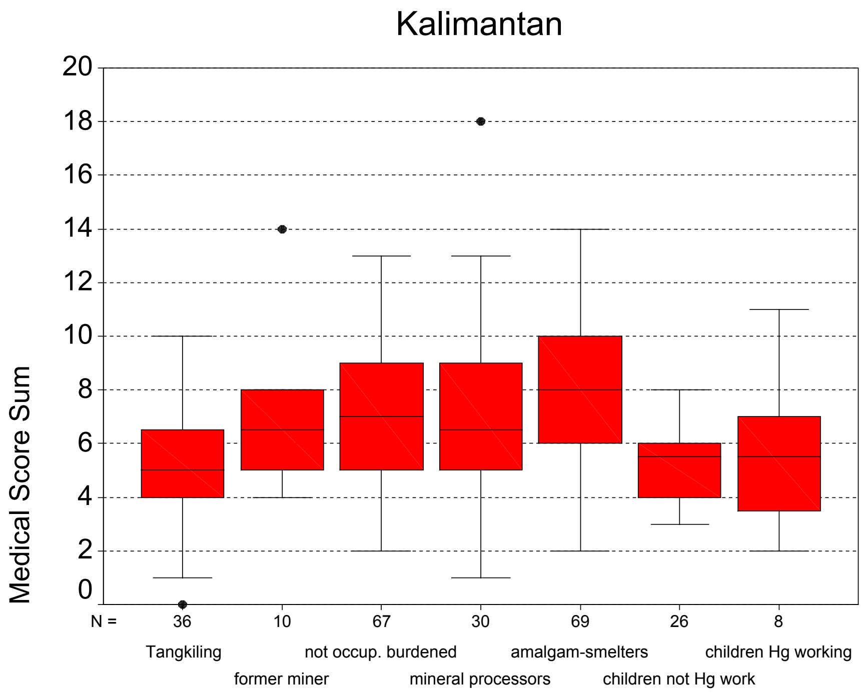


Figure 57 - Medical score sum of different sub-groups in Kalimantan.

3.7.9. Statistical analysis of mercury levels versus clinical data

Correlation tests between mercury concentrations in the bio-monitors and clinical data were performed on the sub-groups of the amalgam-burners from both areas only. These groups were selected, because they were the highest burden groups with the highest mercury concentration in the bio-monitors and the highest frequency of health disturbances, characteristic for a mercury burden. Performing the same analysis including all investigated persons, or all volunteers from the gold mining areas, will just "water down" the results.

As can be seen from tables 18 to 25, just a few of the medical data correlate significantly to the Hg concentration in the bio-monitors (Chi-square-test, Spearman rank correlation).

Table 18 - Significant correlations between anamnestic data and mercury concentration in bio-monitors (group of amalgam-burners from Sulawesi only, n = 61). * = p < 0.05.

Anamnestic data	Hg-Urine (µg/g creatinine.)	Hg-Blood	total Hg-Hair	MeHg-Hair
Male/female	-	-	-	-
Age	-	-	-	-
Alcohol consumption	-	-	-	-
Metallic taste	-	-	-	-
Salivation	-	-	-	-
Tremor daily	-	-	-	-
Tremor at work	-	-	-	-
Sleeping problems	-	-	-	-
Health problems worsened since Hg exposed	-	-	-	-
Lack of appetite	-	-	-	-
Sleep disturbances	-	-	-	-
Easily tired	-	-	-	-
Loss weight	-	-	-	-
Rest more	-	-	-	-
Feel sleepy	-	-	-	-
Problems to start things	-	-	-	-
Lack of energy	-	-	-	-
Less strength	-	-	-	-

Table 18 (Cont.)- Significant correlations between anamnestic data and mercury concentration in bio-monitors (group of amalgam-burners from Sulawesi only, n = 61). * = p < 0.05.

Anamnestic data	Hg-Urine (µg/g creatinine.)	Hg-Blood	Total Hg-Hair	MeHg-Hair
Weak	-	-	-	-
Problems with concentration	-	-	-	-
Problems to think clear	-	-	-	-
Word finding problems	-	-	-	-
Eyestrain	-	-	-	-
Memory problems	-	-	*	*
Feel nervous	-	-	-	-
Feel sad	-	-	-	-
Headache	-	-	-	-
Nausea	-	-	-	-
Numbness	-	-	-	-

Table 19 - Significant correlations between clinical data and mercury concentration in bio-monitors (group of amalgam-burners from Sulawesi only, n = 61) . * = p < 0.05.

Clinical Data	Hg-Urine (µg/g creatinine.)	Hg-Blood	Total Hg-Hair	MeHg-Hair
Bluish coloration of gingiva	-	-	-	-
Gingivitis	-	-	-	-
Ataxia of gait	-	-	-	-
Finger to nose tremor	-	-	-	-
Finger to nose dysmetria	*	*	*	-
Dysdiadochokinesia	-	-	-	-
Tremor of eyelid	-	-	-	-
Field of vision	-	-	-	-
Heel to knee ataxia	-	-	-	-
Heel to knee tremor	-	-	-	-
PSR pathologic	-	-	-	-
BSR pathologic	-	-	-	*
ASR pathologic	-	-	-	-

Table 19 (Cont.) - Significant correlations between clinical data and mercury concentration in bio-monitors (group of amalgam-burners from Sulawesi only, n = 61) . * = p < 0.05.

Babinski reflex positive	-	-	-	-
Mento-labial reflex positive	-	-	-	-
Bradykinesia	-	-	-	-
Hypomimia	-	-	-	-
Proteinuria	-	-	-	-

Table 20 - Significant correlations between neuro-psychological test classes and mercury concentration in bio-monitors (group of amalgam-burners from Sulawesi only, n = 61). * = p < 0.05.

Neuro-psychological test	Hg-Urine (µg/g creatinine.)	Hg-Blood	Total Hg-Hair	MeHg-Hair
Memory test	*	-	-	-
Matchbox test	-	-	-	-
Frostig test	*	*	*	-
Pencil tapping test	-	-	-	-

Table 21 - Significant correlations between medical scores and mercury concentration in bio-monitors (group of amalgam-burners from Sulawesi only, n = 61). * = p < 0.05.

Medical Scores	Hg-Urine (µg/g creatinine.)	Hg-Blood	Total Hg-Hair	MeHg-Hair
Anamnestic score	-	-	-	-
Clinical score	-	-	-	-
Neuro-psychological test score	-	-	-	-
Medical score sum	-	-	-	-

Table 22 - Significant correlations between anamnestic data and mercury concentration in bio-monitors (group of amalgam-burners from Kalimantan only, n = 69). * = p < 0.05.

Anamnestic data	Hg-Urine (µg/g creatinine.)	Hg-Blood	total Hg-Hair	MeHg-Hair
Male/female	*	*	-	-
Age	-	-	-	-
Alcohol consumption	-	-	-	-
Metallic taste	-	-	-	*
Salivation	-	*	*	*
Tremor daily	-	-	-	-
Tremor at work	-	-	-	-
Sleeping problems	-	-	-	-
Health problems worsened since Hg exposed	*	-	-	-
Lack of appetite	-	-	-	-
Sleep disturbances	-	-	-	-
Easily tired	-	-	-	-
Loss weight	-	-	-	-
Rest more	-	*	*	-
Feel sleepy	*	*	*	-
Problems to start things	*	-	-	-
Lack of energy	*	*	*	-
Less strength	*	*	*	-
Weak	*	*	*	-
Problems with concentration	-	-	-	-
Problems to think clear	-	-	-	-
Word finding problems	*	*	*	*
Eyestrain	-	-	*	-
Memory problems	-	*	*	*
Feel nervous	-	-	-	*
Feel sad	-	-	-	-
Headache	-	-	-	-
Nausea	-	-	-	-
Numbness	*	-	-	-

Table 23 - Significant correlations between clinical data and mercury concentration in bio-monitors (group of amalgam-burners from Kalimantan only, n = 69) . * = p < 0.05.

Clinical data	Hg-Urine (µg/g creatinine.)	Hg-Blood	Total Hg-Hair	MeHg-Hair
Bluish coloration of gingiva	-	-	-	-
Gingivitis	-	-	-	-
Ataxia of gait	-	-	-	-
Finger to nose tremor	-	-	-	-
Finger to nose dysmetria	-	-	-	*
Dysdiadocho-kinesia	-	-	-	-
Tremor of eyelid	-	-	-	-
Field of vision	-	-	-	-
Heel to knee ataxia	-	-	-	-
Heel to knee tremor	-	-	-	-
PSR pathologic	-	-	-	-
BSR pathologic	-	*	-	-
ASR pathologic	-	-	-	-
Babinski reflex prositive	-	-	-	-
Mento-labial reflex positive	-	-	-	-
Bradykinesia	-	-	-	*
Hypomimia	-	-	-	-
Proteinuria	-	-	-	-

Table 24 - Significant correlations between neuro-psychological test classes and mercury concentration in bio-monitors (group of amalgam-burners from Kalimantan only, n = 69). * = p < 0.05.

Neuro-psychological test	Hg-Urine (µg/g creatinine.)	Hg-Blood	Total Hg-Hair	MeHg-Hair
Memory test	*	-	-	-
Matchbox test	-	-	-	-
Frostig test	*	*	*	-
Pencil tapping test	-	-	-	-

Table 25 - Significant correlations between medical scores and mercury concentration in bio-monitors (group of amalgam-burners from Kalimantan only, n = 69). * = p < 0.05.

Medical Scores	Hg-Urine (µg/g creatinine.)	Hg-Blood	Total Hg-Hair	MeHg-Hair
Anamnestic score	-	-	-	*
Clinical score	-	-	-	-
Neuro-psychological test score	-	-	-	-
Medical score sum	-	-	-	-

3.7.10. Discussion of the Statistical Analysis

The relatively poor correlation of classic clinical signs of mercury intoxication to the mercury concentrations in the bio-monitors (blood, urine, hair, MeHg hair) of the amalgam-burners may be explained by factors like:

The mercury concentration in the target tissues, especially the brain, correlates to the mercury concentration in bio-monitors like urine, blood or hair. This correlation is statistically significant and good enough to mirror different burden of different groups (here e.g. workers, non-workers and controls). But the inter-individual differences are so large that it is rather pointless to conclude the heavy metal burden in the target tissue of an individual from the concentration in the bio-monitors (Drasch 1997).

Most of the amalgam-burners are chronically burdened by mercury and not only acute. This means that a reversible or even irreversible damage of the central nervous system may be set months or years before the actual determination of the mercury concentration in the bio-monitors under a quite different burden. The medical score sum distinguishes well between the control group and the amalgam-burners.

3.7.11. Decision for the Diagnosis of a Chronic Mercury Intoxication

For the different Hg burdened groups (< HBM I; HBM I - HBM II; HBM II - BAT; > BAT) no striking differences in the results of the medical and neuro-psychological tests could be seen (for possible reasons, see above). Therefore at least a chronic mercury intoxication could not be diagnosed on the basis of the blood, urine and/or hair concentration alone, to what values ever the threshold limits are set (see above). An intoxication is defined by the presence of the toxin in the body and typical adverse health effects. Deriving from this interpretation we have tried to find a balanced result by the combination of mercury concentration in blood, urine and hair and the negative health effects, as summarised in the medical score sum, as described above in detail (Drasch 2001). The medical test scores were divided in three groups, according to the quartiles (0-25%, 25-75%, 75-100%). Table 26 shows this combination. This definition of mercury intoxication was committed with UNIDO, to get comparable results in the different sites in the global project (Veiga 2003).

Table 26 - Decision for the diagnosis "chronic mercury intoxication".

		Medical Score Sum		
		0 – 4	5 – 9	10 - 21
Hg in all bio-monitors	< HBM I	–	–	–
Hg at least in one bio-monitor	> HBM I	–	–	+
	> HBM II	–	+	+
	> BAT	+	+	+

In principle this means, that the higher the mercury concentration in at least one of the bio-monitors was, the lower the number of adverse effects for a positive diagnosis of a mercury intoxication must be and vice versa.

Cases with only moderately elevated mercury levels (i.e. between HBM I and HBM II) are taken for positive, too, if the medical test scores are in the upper quartile region (score sum 10-21).

The case, that a mercury concentration above the occupational threshold limit BAT alone (this means without clinical signs, i.e. medical sum score 0-4) is responsible for the classification of intoxication, is rare. Just five cases out of 48 with mercury concentrations above the BAT limits showed medical sum scores below 4.

Prevalence of the Diagnosis "Mercury Intoxication"

By this classification the results shown in the Tables 27 and 28 and the Figures 58 – 60 were obtained. As expected, no volunteer from the control area of Air Mandidi in Northern Sulawesi has been found to be mercury intoxicated. In contrast to this, more than 20% of the "control group" from Tangkiling in Central Kalimantan had to be classified as mercury intoxicated. The markedly higher frequency of most clinical signs of a mercury intoxication in this area is in good agreement with the elevated mercury level in the bio-monitors, as found in this population. It must be derived from a methyl-mercury exposure, probably by fish, in this area.

Table 27 - Frequency of mercury intoxication in Sulawesi.

Group	Total number	Number of mercury intoxicated cases	% cases, mercury intoxicated
Control adults in Air Mandidi	22	0	0
Not occupational Burdened in Tatelu	18	2	11.1%
Mineral processors in Tatelu	17	4	23.5%
Amalgam-burners in Tatelu	61	33	54.1%
Control children in Tatelu	31	0	0
Children not working with Hg in Tatelu	22	0	0
Children working with Hg in Tatelu	51	9	17.6%

Table 28 - Frequency of mercury intoxication in Kalimantan (* = should not be over interpreted due to low case numbers).

Group	Total number	Number of mercury intoxicated cases	% cases, mercury intoxicated
Population in Tangkiling	36	8	22.2%
Former miner, now living in Tangkiling	10	4	40.0% *
Not occupational burdened in Kereng Pangi	67	23	34.3%
Mineral processors in Kereng Pangi	30	13	43.3%
Amalgam-burners in Kereng Pangi	69	41	59.4%
Children not working with Hg in Kereng Pangi	27	5	18.5%
Children working with Hg in Kereng Pangi	8	2	25.0% *

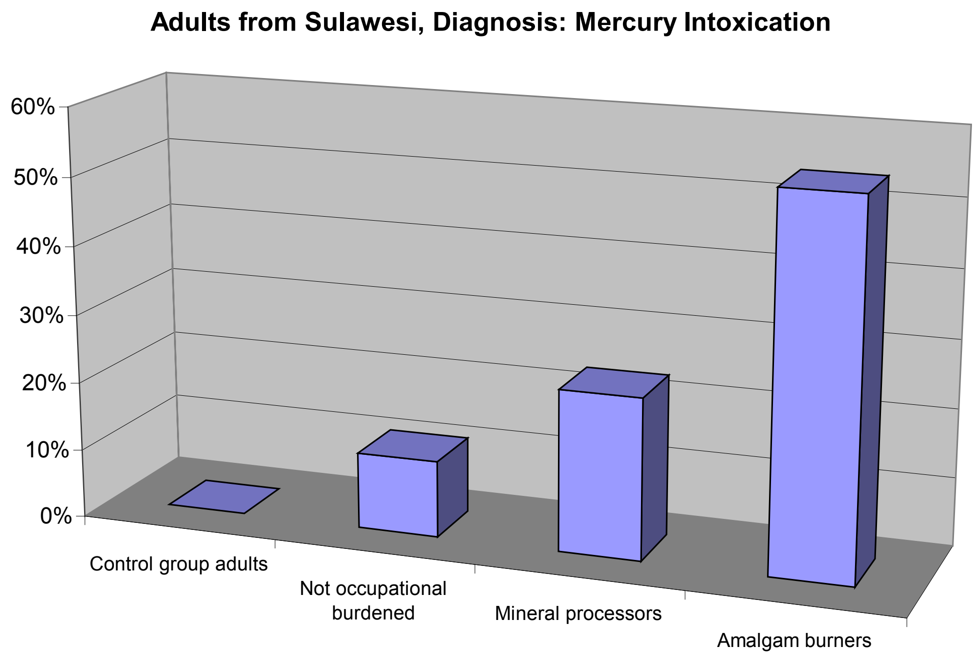


Figure 58 - Adults from Sulawesi, frequency of the diagnosis "mercury intoxication".

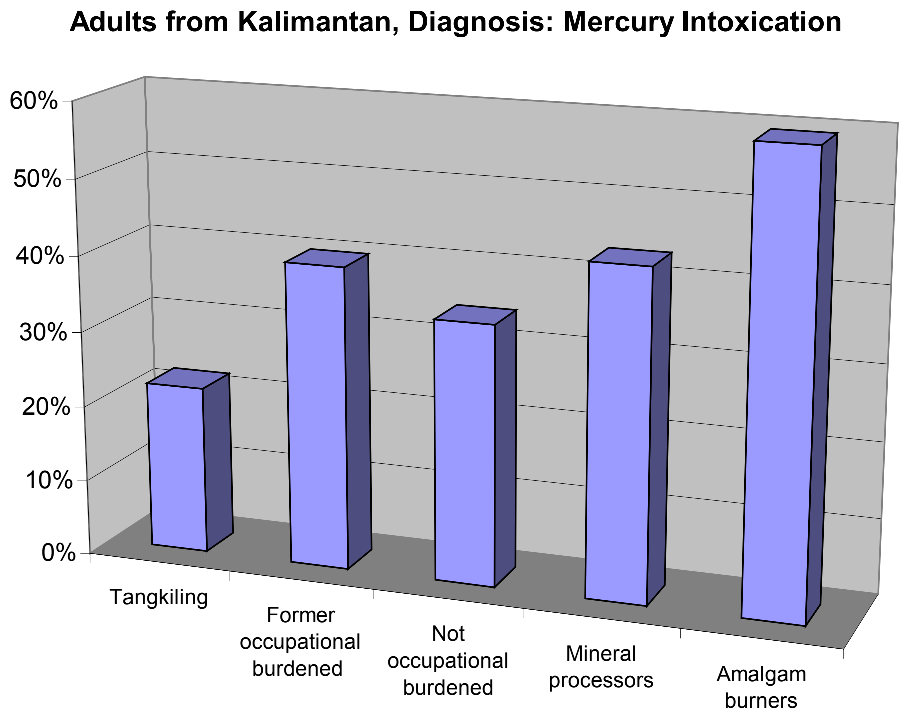


Figure 59 - Adults from Kalimantan, frequency of the diagnosis "mercury intoxication".

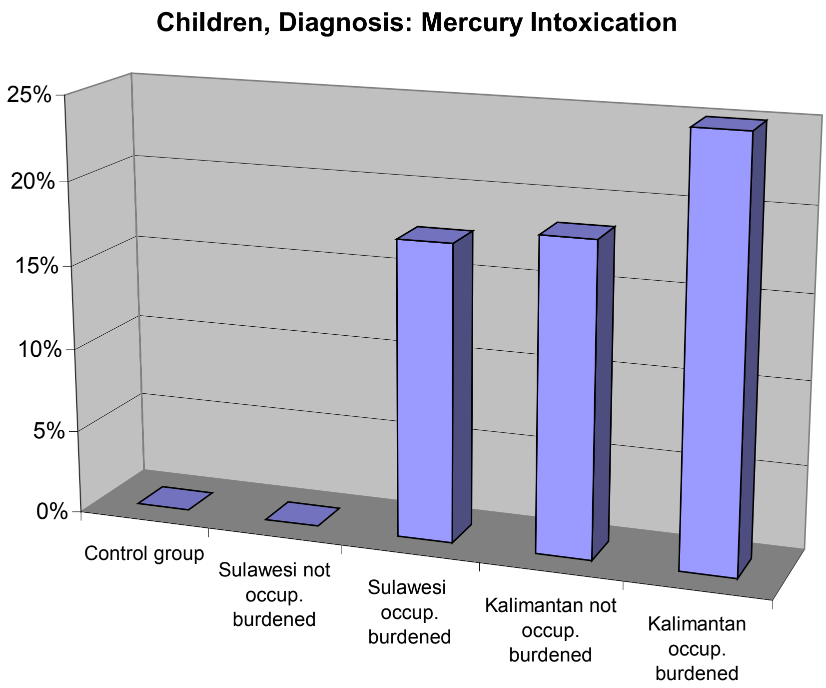


Figure 60 - Children, frequency of the diagnosis "mercury intoxication".

Within the groups of amalgam burners in Sulawesi and Kalimantan the frequencies of mercury intoxications are similar. More than half of the amalgam burners were diagnosed to be mercury intoxicated (54.1% and 59.4%). This percentage is high but in comparison to the region of Mt. Diwata in the Philippines (Drasch 2001, Boese-O'Reilly 2003), significantly lower. Using the same protocol, we found the percent of diagnosed mercury intoxicated amalgam burners in this area totalled 85,4% (!). In contrast, the maximal mercury burden (as expressed in the top mercury concentrations found in the bio-monitors) was remarkably higher in Indonesia, especially in Galangan in Kalimantan, than on Mt. Diwata (**see tables 6 and 7, appendix 1**).

The frequency of intoxications in the not directly mercury burdened populations in the gold mining areas ("not occupational burdened" and the mineral processors) is higher in the gold mining area of Galangan in Kalimantan than in the gold mining area of Tatelu in Sulawesi (**see tables 6 and 7, appendix 1).**

In both gold mining regions mercury intoxicated children were found, especially those who worked with mercury (**table 8, appendix 1**). The lower percentage of intoxications in comparison to the adults results possibly from the shorter period of time, the children are exposed.

3.7.12. Influence on Nursed Babies

One major problem of mercury is a known adverse effect on the growing foetus and baby due to a high maternal burden and a cross of mercury through the placenta or to the breast-milk. High numbers of miscarriages, stillbirths and birth defects have been reported as consequence of the mass intoxication with mercury in Minamata, Japan, 1956 or the Iraq, 1972/73 (Drasch 2004a). This project in Indonesia was not designed to detect possible adverse effects on the foetus, but as a side result some data on mercury in breast-milk samples were obtained.

22 samples of mature breast-milk were collected (19 in Kalimantan and 3 in Sulawesi) and analysed for total mercury. In Table 29 the cases from Kalimantan are shown individually in decreasing order of the Hg concentration in the breast-milk samples. In the three samples from the Sulawesi mining area concentrations of 1.8, 1.5 and 1.3 µg Hg/ L milk were found. For comparison: In some recent studies from Germany samples from mature breast-milk maximal mercury concentrations below 2 µg/L have been found (Drasch 1998). Approximately half of the samples from Kalimantan are in this normal background region. But at least one sample from the mining area shows an extreme high mercury concentration (43.2 µg/L). The mother had been identified as "intoxicated", despite a relatively moderate mercury concentration in her bio-monitor. A full nursing of a baby with approximately 850 ml breast-milk per day with this mercury concentration of 43.3 µg/L, results in a daily uptake of approx. 37 µg inorganic mercury. US EPA has calculated the so-called "Reference Dose" for inorganic mercury to 0.3 µg/ kg body weight and day (US EPA 1997). For a 6 kg baby this means a maximum daily uptake of 1.8 µg inorganic mercury. The real uptake of this baby was 20 times higher. Moreover it must be considered that the absorption rate for inorganic mercury especially from milk in the gastro-intestinal tract of babies is markedly higher than of adults (Drasch 2004a).

Table 29 - (Total) mercury concentration in breast-milk samples from Kalimantan, compared to other data from the mothers.

Area	Mother's Profession	Hg-Breastmilk (µg/L)	Total-Hg Hair (µg(g)	MeHg-Hair (µg/g)	Hg-U (µg/ g creatinine)	Hg-B (µg/L)	Mother intoxicated
Mining area	other job	43.2	4.19	2.82	11.1	42.4	yes
Mining area	other job	14.1	103.19	51.09	53.0	27.7	yes
Mining area	other job	9.5	4.41	2.24	5.0	8.5	no
Mining area	other job	5.9	1.93	1.25	5.3	9.7	no
Mining area	other job	5.2	1.18	0.36	11.8	14.9	yes
Mining area	other job	4.6	2.06	1.42	4.5	6.4	no
Mining area	other job	4.4	1.56	0.90	2.3	10.5	no
Mining area	other job	3.8	3.21	2.50	2.7	9.0	no
Mining area	other job	3.5	2.46	1.82	3.2	4.5	no
Mining area	other job	3.2	2.20	1.58	2.8	6.0	no
Mining area	other job	1.9	0.94	0.22	1.5	3.8	no
Mining area	other job	1.3	2.55	1.69	1.8	6.2	no
Mining area	other job	1.3	22.82	4.98	19.2	36.5	yes
Mining area	amalgam-burner	1.2	3.19	2.67	3. 9	6.1	no
Mining area	mineral processor	1.1	5.35	2.28	4.1	5.2	yes
Tangkiling	other job	2.4	2.86	2.08	4.4	12.2	no
Tangkiling	other job	1.9	1.96	1.79	0.7	10.8	no
Tangkiling	other job	0.5	1.03	0.94	0.3	5.7	no
Tangkiling	other job	0.5	1.03	0.92	0.5	4.8	no

The second case (Hg-Milk = 14.1 µg/L) gave even more rise to concern: This mother showed extreme high concentrations of total mercury (103 µg/g) and methyl-mercury (51 µg/g) in her hair. She belongs to the small group which was found to be extreme burdened by methyl-mercury, probably due to the consumption of fish from the mercury contaminated pit holes (see above). This single case can be directly compared to mothers from the Seychelles or the Faeroes Islands, which are predominantly burdened by methyl-mercury from fish. Her mercury hair concentration is by a factor of 100 (!) higher than the safety limit, as calculated by US EPA (1997) for methyl mercury in maternal hair.

3.7.13. Screening of Mercury Urine Concentration in Field

Figure 61 - Hg analyser Hg-254 NE, Seefelder Messtechnik, Seefeld, Germany.

On field a mobile Hg analyser (Hg-254 NE, Seefelder Messtechnik, Seefeld, Germany) was used to screen for inorganic mercury in urine. In a beaker, 1ml urine was diluted with 100 ml water (bottled drinking water). A 2 ml solution of 10% tin(II)chloride in 6N hydrochloric acid was added , the system closed, and the formed mercury vapour in the gas phase above the liquid transferred in a closed loop to a quartz cell, where it was detected by atomic emission spectrometry. Bottled drinking water (as to be got locally) was used for zero standard, and a mercuric nitrate solution for standard. The limit for a quantitative detection was approximately 2 µg/L urine. Due to practicability, an upper limit of 200 µg/L was established for field application. As the HBM limits for Hg in urine are 7 and 25 µg/L, respectively (see Table 17), this method seems to be sufficient sensitive for urine Hg screening in the field. One analysis lasts approximately 3 minutes. 465 urine samples could be analysed with this method in field. Out of them, 265 were below the detection limit (2 µg/L) and 10 above (200 µg/L). In 190 cases inorganic mercury concentrations between 2 and 200 µg/L could be detected quantitatively.

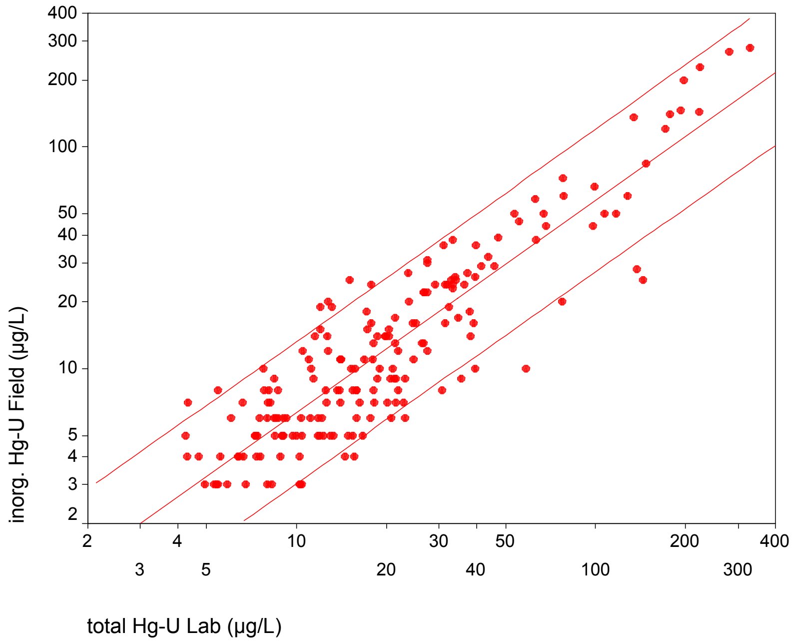


Figure 62 - Comparison of the concentration of inorganic Hg-U, as determined in field and the total Hg-U concentration, as determined in the lab (Linear regression line and 90% confidence intervals).

The correlation between the concentration of inorganic Hg, determined with this method in field, and the concentration of total Hg, as determined in lab, was excellent (Spearman-r_o = + 0.85, n = 190, statistical highly significant). A scatter plot of the results between 2 – 200 µg/L (Figure 62) proves the sufficient correspondence of both methods. In 10 cases urine concentrations higher than 200 µg/L were measured in field. In all these cases this was proved in the lab with total Hg-U concentrations far above 200 µg/L (330 – 5,240 µg/L). In all cases of inorganic Hg-U values in field below the detection limit of 2 µg/L, low total Hg-U values (up to 10 µg/L) were found in the lab, too. It must kept in mind that with this field method just inorganic mercury can be detected. But at least in the mining areas of Kalimantan and Sulawesi most of the mercury burden of men is inorganic. Furthermore it is known, that inorganic mercury is much better urinary excreted than organic bound mercury like methyl-mercury. From this it could be concluded that most mercury in the urine samples has been in the inorganic form. Nevertheless, as expected, in the mean the total mercury concentration in urine (as detected in the lab), was higher than the inorganic mercury concentration determined in field (see regression line in Table 30).

Table 30 - Comparison of the preliminary classified "mercury intoxicated" in field and by all lab results.

		Field Result		Total
		intoxicated	not intoxicated	
Lab. Result	intoxicated	82	61	143
	not intoxicated	4	318	322
Total		86	379	465

All data from the medical investigations and from the urine screening were put during the field project into an excel data sheet . The medical sum score could be calculated and 86 cases preliminary classified as "mercury intoxicated" by the combination of the medical sum score and the Hg concentration in urine, as determined in field (according to Table 30). From the medical sum score and the final lab results, 82 out of these 86 intoxications could be confirmed. Only in 4 (!) cases the primarily field diagnosis could not be confirmed. In this cases in field a higher Hg concentration was determined than afterwards in the lab. The total number of finally (i.e. after the Hg determination in all three bio-monitors in the lab) diagnosed intoxications was 143. In the remaining 61 cases, the intoxication was diagnosed by elevated Hg concentrations in blood and/or hair. Overall, the urine mercury screening during the field project has proved to be a sound method to get quick information during the field project on the order of magnitude of the mercury burden of sub-groups of the population. Together with a computer based evaluation of the medical results during the field project it was possible in more than one half of the cases to find out mercury intoxicated individuals just during the field mission and to give a primarily estimation of the local burden situation. Nevertheless, the remaining 61 cases of intoxication underline the necessity to take in addition blood and hair samples in field and analyse them later in the lab. This is to remind especially in the case of a predominant burden with methyl-mercury like in the "control area" of Tangkiling in Central Kalimantan.

4. Conclusions and Recommendations

Although mercury is heavily burdening the environment in North Sulawesi, health hazards due to methylmercury exposure, as indicated by results in fish, hair, blood and breast milk, are more likely occurring in Central Kalimantan. This may be explained by a combination of factors, namely the adverse living conditions in Galangan that make the population dependent on fishing in flooded open pits; a high mercury bioavailability in dark water systems, and an increased mercury background in the local environment, as indicated by the environmental assessment. In contrast, there is a lack of pathways between methylmercury present in the environment and the local population in North Sulawesi, since the availability of fish in the Talawaan River is very limited, resulting in consumption from marine fish. On the other hand, 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.

It was estimated 130 milling operations in the Talawaan watershed (Tatelu region) and found out that mill operators have purchased from 10 to 15 kg of mercury/month/milling unit. A unit with 12 mills recovers 4 to 6 g of gold per cycle. Generally there are two cycles per day. The mills operate 8 hours/day, 6 days/week.

According to a mass balance based on both analytical determinations in amalgamation wastes and interviews with the miners, the estimated ratio Hg_{lost} : $Au_{produced}$ in Talawaan falls in the extremely high range of 40 to 60, which is 30 to 40 times higher than average ratios found in SSM worldwide (Veiga and Baker, 2003; Rodrigues-Filho et al, 2004).

Assuming that 9.6 to 14.4 kg of Hg are lost per unit/month, not less than 15 to 22 tonnes of mercury are being released annually in the entire area of Tatelu. This characterizes an alarming mercury burden to the environment in North Sulawesi.

A sampling campaign of soils, sediments, water and biota was conducted in the Talawaan watershed, consisting of 298 samples split into 156 fish samples, and 142 samples of sediments, soils, water, plants and other aquatic organisms, covering the whole study area. The sudy area was divided into 7 sub-areas from the most upstream are down to the estuary.

The most uptream sampling site is located close to the spring of Talawaan river where no mining activity is to be reported. Unexpectedly, Hg levels in those samples were 600 times higher than Hg background levels usually found in sediments in tropical regions (Rodrigues-Filho et al., 2004).

A likely explanation for this anomalous Hg level in unaffected sediments is related to the proximity of the inactive volcano of Mount Kablat, whose former activity might have generated the conditions for the formation of gold deposits in the Tatelu region, as well as their associated Hg enrichment. This Au-Hg association has been observed in other similar gold deposits in North Sulawesi (Turner, 2002).

Approximately 5 km downstream, there an increase of Hg levels in sediments as a consequence of Hg releases from amalgamation wastes to the rivers. Mercury concentrations reach up to 480 μg/g and average 154 μg/g in the sediment fraction < 74 μm.

Further downstream and close to the estuary Hg levels in sediments drop to a mean concentration of 6.7 μg/g, which is even lower than those encountered in the most upstream part of the river, indicating a dilution effect caused by runoff of catchment soils.

As for the assessment of Hg bioavailability through using bioindicators other than fish, like aquatic plants and mollusks, it has been indicated that Hg is being taken up by living organisms in the Talawaan River, as shown by the distribution of Hg in aquatic plants and mollusks. Mercury uptake by aquatic plants is particularly evident in cyanidation tailings, where Hg concentrations reach up to 370 µg/g. This is likely a consequence of increasing Hg mobility and biovailability through the formation of mercury-cyanide complexes after cyanidation of highly contaminated amalgamation wastes.

Therefore, it is assumed that both factors are contributing to this indicated high Hg bioavailability, namely an anomalous Hg background in the area and the cyanidation of amalgamation wastes forming soluble mercury complexes.

Central Kalimantan (Galangan)

Gold mining is carried out following traditional methods also used in the Brazilian gold mining areas (secondary deposits) in the Amazon region. In open pits the gold bearing layers are hosted down by means of hydraulic monitors. Manual amalgamation of the concentrate is done in ponds consisting of flooded open pits excavated beside the miner's residences, being Hg-contaminated tailings left in those ponds.

According to a mass balance based on both analytical determinations in amalgamation wastes and interviews with the miners, the ratio Hg_{lost} : $Au_{produced}$ in Galangan is estimated in the range of 1.5 to 2, which is an average ratio found in SSM worldwide (Veiga and Baker, 2003; Rodrigues-Filho et al, 2004). Assuming that 150 to 300 g of mercury are lost per unit/month, 1 to 2 tonnes of mercury are being released annually in the entire area.

Amalgam is burned in gold shops, commercial stores in a chimney-like construction, which leads the mercury vapor just outside the house by an outlet pipe. The gold shops are situated in the middle of the village. There is no proper ventilation for the mercury fumes, where in the rainy season 15 kg of gold is sold to 20 gold shops and melted in the village, releasing at least 200 kg/annum of mercury in the village. Housing areas, food stalls and a school are just nearby.

Mercury concentrations in sediments of the Katingan River are in general significantly lower than in the Talawaan River in North Sulawesi. This is likely related to both a less polluting mineral processing technique used in Galangan and an existing lower Hg background in the Katingan Basin. This is indicated by relatively low Hg levels present in sediments that have been deposited many years before starting SSM activities in the region. Lower sections of sediment cores taken in riversides and floodplains of the Katingan River are assumed to mirror the existing sedimentological conditions prior to disclosure of the gold rush.

Distribution of mercury concentrations in a sediment core from the Katingan River, upstream of mining sites, shows significantly lower levels, averaging 0.38 μg/g, than in the cores taken downstream of the mining areas, averaging 2.87 μg/g, 2.19 μg/g and 2.33 μg/g, respectively in sediment cores A301, A501 and A601. Therefore, the Hg range found in core 201 indicates an existing Hg background for this study area.

Moreover, the sediment cores taken downstream have a similar varying distribution of Hg levels with depth, showing a common peak of Hg concentration between depths from 6 to 12 cm. This Hg peak is likely related to a major Hg release from the mining sites some years ago that probably mirrors a more intense Hg use at the beginning of the gold rush in 1998.

A wide range of mercury concentrations within unaffected sediment sections, from 0.1 to 1.2 μg/g, averaging 0.38 μg/g, indicates an uncommon situation that geochemically has no correspondence to previous studies conducted in the Brazilian Amazon (Rodrigues-Filho and Maddock, 1997, Rodrigues-Filho et al., 2002). This is likely due to the geological setting in Indonesia.

The distribution of mercury concentrations in individual sediment samples from the Galangan mining site resembles the levels found along the downstream section of the Katingan River. This a clear indication that sediments from both the mining site and the lower Katingan River are closely related to each other as a consequence of mercury discharges from SSM operations. Nevertheless, those Hg concentrations in the Galangan region are at least one order of magnitude lower than in the Talawaan region.

The prevailing sandy composition of the mining tailings that is driven by the type of alluvial deposit with almost no silt-clay fraction is a likely explanation for the relatively low levels, since Hg released during amalgamation finds no particulate surface to be adsorbed on, leading to Hg concentrations even lower than in river sediments.

On the other hand, although a relatively moderate Hg contamination degree in amalgamation tailings is to be reported for Galangan, there are strong indications that mercury finds a favorable condition for becoming highly mobile as indicated by the abnormally high levels found in the organic fine cover of the tailings, composed basically of algae. This is an indication that mercury is being dissolved by the organic dark waters of Galangan, which is a potentially favorable condition for increasing mercury bioavailability through methylation.

Mercury in Fish – North Sulawesi and Central Kalimantan

The present results show that total mercury concentrations in fish from North Sulawesi are higher than in fish from Central Kalimantan area. The resulted mean Hg level from Central Kalimantan is 0.21±0.36 μg/g (N=263) and its maximum value is 1.83 μg/g, while in North Sulawesi mean Hg level is 0.58±0.45 μg/g (N=130) and its maximum value reachs 2.60 μg/g.

The mean concentration of Hg (0.36 μg/g) in fish species from this work was within that range and lower than 0.5 μg/g, the Hg concentration in fish recommended by WHO (1990) as limit for human protection by Hg exposure by fish consumption.

In North Sulawesi, Hg levels in fish from Toldano river (reference area-T6) showed the lowest mercury levels, averaging 0.02 μg/g, while T2, a dam reservoir close to the mining sites, showed the highest mercury levels in fish, 0.85 μg/g being considered as the most contaminated site in the area. However, we have to take into account that these species are smaller and lighter than fish from other aquatic systems influenced by gold mining, such as Amazon region, suggesting that Hg bioavaliability in Manado can be higher than in Central Kalimantan.

In Central Kalimantan area, fish from flooded open pits in mining site areas showed the highest Hg levels. These open pits are used for gold processing and, also, for fishing, bathing and domestic wastes collected. While the average of Hg in fish from the whole study area are quite low, the Hg levels in fish from the flooded open pits surrounding garimpos´s area are considered as the most contaminated site. As miners and their families are living close to those open pits and might often consume those fish, this charaterizes a potential pathway for methylmercury exposure to the local population.

By employing the risk assessment to human health, toxicological, rather than simply statistical, significance of the contamination can be ascertained. At a screening level, a Hazard Quotient (HQ) approach (USEPA, 1989), assumes that there is a level of exposure (i.e., RfD = Reference of Dose) for non-carcinogenic substances below which it is unlikely for even sensitive populations to experience adverse health effects.

In Central Kalimantan, it should be considered that miners living close to the P4 study site may consume fish caught in those flooded open pits. As they are not riverside population, but considering the poverty, one could assume the fish consumption rate close to 0.05 $Kg.d^{-1}$. The resultant HQs for MeHg fall above the unit for North Sulawesi considering the fish market consumption. For Central Kalimantan, both total and P4 sampling site, HQ resulted above the unity, 2.4 and 9.9, respectively, which means that population are subject to potential health hazards due to fish consumption. This conclusion is fully in agreement with the indications achieved by the health assessment.

Health Assessment – North Sulawesi and Central Kalimantan

The extraction of the gold with liquid mercury releases serious amounts of mercury, especially high toxic mercury fumes into the local environment. The health status of 492 volunteers in Sulawesi and Kalimantan was assessed with a standardised health assessment protocol from UNIDO (Veiga 2003) by an expert team from the University of Munich/Germany in August/September 2003.

In Kalimantan a control group, mainly women, shows unexpectedly increased Hg levels in blood and hair. Nevertheless, this is in accordance with the indications from the environmental assessment, namely a elevated Hg background in sediments, a reatively high Hg mobility and a high Hg biovailability, which is likely related to existing dark water rivers in the area.

The mercury levels in the bio-monitors urine, blood and hair were significantly higher in all exposed populations than in the control group. Mainly amalgam-smelters showed mercury levels above the toxicological threshold limit HBM II in urine, blood and hair. Mainly inorganic mercury contributes to the high body burden of the workers.

Some few cases, all from Galangan in Kalimantan, showed extreme high mercury concentrations in blood and extreme high concentrations of organic bound mercury in hair. This may be explained by fishing in heavily mercury contaminated pit holes in this mining area, as observed from the results of Hg in fish from the flooded open pits.

Typical symptoms of mercury intoxication were prevalent in the exposed groups. The medical score sum plus the bio-monitoring results made it possible to diagnose in Tatelu (Sulawesi) in 33 out of 61 amalgam-smelters the diagnosis of a chronic mercury intoxication, and in 4 out of 17 mineral processors. Within the other population in Tatelu 2 out of 18 people showed a mercury intoxication. In the control group there was no case of a mercury intoxication.

In Kereng Pangi (Kalimantan) in 41 out of 69 amalgam-smelters the diagnosis of a chronic mercury intoxication was made, and in 13 out of 30 mineral processors. Within the other population in Kereng Pangi 23 out of 67 people showed a mercury intoxication. In the Tangkiling group 8 out of 36 people were found to be intoxicated, and 4 out of 10 former miners.

Children working with mercury were found as intoxicated in 9 out of 51 children in Tatelu, and 2 out of 8 children in Kereng Pangi. Children not working, but living in the exposed areas were intoxicated in 5 out of 27 cases in Kereng Pangi and in no case in Tatelu. None of the children from the control area intoxicated.

The percentage of intoxications among amalgam-smelters is similar in Tatelu (54,1%) and Kereng Pangi (59,4%). In Rwamagasa / Tanzania 25,3% of amalgam smelters were found to be intoxicated, and in the gold mining area of Mt. Diwata in the Philippines, 85.4 % of the amalgam-smelters were intoxicated (Drasch 2004b, Drasch 2001). The difference cannot be explained by a different, i.e. a safer burning technique in Rwamagasa. Moreover, it must kept in mind, that the maximal burden (as expressed in the top mercury concentrations found in the bio-monitors) was even higher than in Mt. Diwata. In the less exposed population and the children, the rates of intoxication are much higher in Kereng Pangi.

A hypothesis for these differences is not to be found in the various amalgam smelting techniques. The main difference between Tatelu and Kereng Pangi is, that in Tatelu the general population does not live within the mining area itself, so they are less exposed. And the difference to Mt. Diwata is that the Galangan area around Kereng Pangi is flat compared the mountainous area of Mt. Diwata. The difference to Tanzania might be explained by the much lower exposure to liquid mercury in Rwamagasa, due to a lower output of gold from the ore.

Nursed babies of mothers living in Kereng Pangi are at special risk. In 10 out of 15 breast-milk samples of nursing mothers, mercury levels were above comparison levels of 2 μg/l. In two cases the levels were extremely high, well above reference dose levels of US-EPA.. In addition to a placental transfer of mercury during pregnancy from the mother to the foetus (as has been proved in other studies) this high mercury burden of nursed babies is a new, up to now unknown health hazard in mining communities.

Poverty is a main reason for the bad health status of the small-scale mining communities. Struggling for pure survival makes mining for gold a necessity to find any financial resource. The daily fight of survival forces the miners put their own health and the health of their children at risk.

A reduction of the release of mercury vapours from small-scale gold mining as in Indonesia into the atmosphere will not only reduce the number of mercury intoxicated people in the mining area proper. It will reduce the global Hg pollution in the atmosphere.

Mercury is a serious health hazard in the small-scale gold mining areas of Tatelu (Sulawesi) and Kereng Pangi (Kalimantan). Working for many years in the amalgamation or burning process, especially amalgam-burning resulted in severe symptoms of mercury intoxication. The exposure of the whole community to mercury is reflected in raised mercury levels in the urine, and symptoms of brain damage like ataxia, tremor and movement disorders. In over 50% of the amalgam-smelters from both areas a mercury intoxication (according to the definition of UNIDO (Veiga 2003)) was diagnosed. Former miners, mineral processors and the general population in the mining areas were also intoxicated. Especially frightening is the high levels of mercury in breast milk samples in Kereng Pangi (Kalimantan), and the high incidence of child labour. This high incidence of child labour ensues in the very early child mercury intoxication in both areas.

How to improve General Health?

Poverty is a main reason for the health and environmental problems.

- At the moment it does not seem to be acceptable that children live in Kereng Pangi or in the mining areas in Tatelu. Missing sanitary standards and high exposure to mercury are the main reasons. Sanitary standards need urgent improvement in Kereng Pangi and in the mining areas of Tatelu.

- The occupational related health risk of mining should be assessed in more detail (accidents, malaria, drinking water quality, sexually transmitted diseases, tuberculosis, HIV / AIDS). One first step to reduce the health hazards in Kereng Pangi might be a proper zoning into industrial areas, commercial areas and housing areas. In Tatelu mainly the workers living on the ground of the ball-mills and in the area of the tunnels are at risk. Imposing basic hygienic standards, such as proper drinking water and reduction of Anopheles mosquitoes in Tatelu mining are and Galangan field area is essential.
- To reduce the obvious risk of accidents in mining sites, raising awareness is necessary. Introducing proper mining techniques is necessary (e.g. tunnel safety in Tatelu and open pit safety in Galangan).
- The risk of sexually transmitted diseases could be reduced, if campaigns for safer sex were introduced
- Smoking habits are very difficult to influence, at least on a local level.
- To improve the health status of the communities the local health service capacities need to be improved.

How to reduce Mercury as a Health Hazard?

Referring to the clinical testing and laboratory results, mercury is a major health hazard in the areas. Some first suggestions are:

- Child labour with highly toxic substances must be stopped immediately. Legal restrictions on child labour need to be immediately implemented.
- Women in childbearing age need special information campaigns on this risk of mercury to the foetus and the nursed baby.
- The participants with intoxication need medical treatment. It is necessary to build up a system to diagnose and treat mercury related health problems in the area. Capacity building including establishing laboratory facilities to analyse mercury in human specimens is required. The financial aspect of treatment and legal problem of importing drugs (chelating agents like DMPS or DMSA, to sweep mercury out of the body) need to be solved. Funding of preventive campaigns and for treatment facilities is now needed.
- Training programs for the health care providers in the Tatelu area and in Kereng Pangi, an other health centres in mining areas to raise awareness of mercury as a health hazard. Awareness raising about HIV risk, e.g. by needle sharing in vaccination programs or safer sex campaigns are needed as well.
- Clinical training of local health workers, including a standardised questionnaire and examination flow scheme (MES = mercury examination score)
- Mercury ambulance: A mobile „mercury ambulance“ might easier reach small-scale miners, than any local health office. As suggested by Mr.

Masayoshi Matsushita (UNIDO Jakarta) a bus or a boat could be used as a mobile mercury ambulance. Equipped with the necessary medical and laboratory utensils, a bus could be driven into the mining areas. Two or three specially trained doctors or nurses could perform the examinations, and begin to carry out treatment. A bus could also be used for health awareness programs (e.g. video equipment). Miners in remote areas might welcome any evening entertainment. Soccer videos might attract more miners to a bus, than much other information material. Why not ask e.g. sponsors for such a bus (or truck).

How to improve the Knowledge on Mercury as a Health Hazard?

- Assessing in a different study design the possibility of mercury related birth and growth defects, increased abortion/miscarriage rates, infertility problems, learning difficulties in childhood or other neuro-psychological problems related to mercury exposure
- Assessing in a different project in more detail the possible transfer of mercury from mother to child via breast-milk and related possible adverse health effects. Females at childbearing age and before need urgently more awareness to refrain from amalgam burning sites, at least during pregnancy and nursing. If this is not possible, a discussion whether to provide them with milk powder and mercury free water (!), and training them to prepare hygienically unobjectionable formula food for their babies needs to be based on a larger data base and a different epidemiological approach.

How to reduce the Release of Mercury into the Environment?

- The exposure to mercury for the miners and the community has to be drastically decreased. Proper mining techniques to reduce the burden of accidents and mercury exposure are essentially needed. Small-scale miners need all possible support to introduce cleaner and safer gold mining and extraction technologies.
- The exposure with mercury is avoidable with such simple technology as retorts. Technical solutions need to go hand in hand with awareness raising campaigns. Technical cooperation, e.g. with GTZ, might be useful.
- To improve the social, health and environmental situation of artisanal small-scale gold miners an alliance of local, regional, governmental and intergovernmental bodies is needed. Cooperation between health and environmental sectors is needed on local, regional, national and intergovernmental level. E.g. UNIDO and WHO in Jakarta could form a nucleus of a national mercury task force.

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Appendix 1

Health Tables

Table 3 - Sulawesi: Spearman' rank correlations (r_o) between the mercury concentration in the different bio-monitors.
**** = p < 0.01 (one-tailed), N = case number**

Hg-B	r_o = + 0.76 ** (N = 221)			
Total Hg-Hair	r_o = + 0.77 ** (N = 219)	r_o = + 0.79 ** (N = 219)		
Inorganic Hg-Hair	r_o = + 0.83 ** (N = 199)	r_o = + 0.68 ** (N = 199)	r_o = + 0.828 ** (N = 199)	
Organic Hg-Hair	r_o = + 0.28 ** (N = 199)	r_o = + 0.45 ** (N = 199)	r_o = + 0.61 ** (N = 199)	r_o = + 0.19 ** (N = 199)
	Hg-U Lab (µg/ g creatinine)	**Hg-B**	**t-Hg-Hair**	**inorganic-Hg-Hair**

Table 4 - Kalimantan: Spearman' rank correlations (r_o) between the mercury concentration in the different bio-monitors.
**** = $p < 0.01$ (one-tailed), N = case number**

Hg-B	r_o = + 0.42 ** (N = 247)			
Total Hg-Hair	r_o = + 0.56 ** (N = 246)	r_o = + 0.71 ** (N = 246)		
Inorganic Hg-Hair	r_o = + 0.80 ** (N = 245)	r_o = + 0.41 ** (N = 245)	r_o = + 0.68 ** (N = 245)	
Organic Hg-Hair	r_o = + 0.18 ** (N = 245)	r_o = + 0.63 ** (N = 245)	r_o = + 0.75 ** (N = 245)	r_o = + 0.19 ** (N = 245)
	Hg-U Lab (µg/ g creatinine)	**Hg-B**	**t-Hg-Hair**	**Inorganic Hg-Hair**

Table 6 - Adults from Sulawesi. Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group on a statistically significant level ($p < 0.05$, one-tailed Chi-square test).

Adults from Sulawesi

Data or Test	**Value or Score**	**Control adults**	**Not occupational burdened**	**Mineral processors**	**Amalgam-burners**
Case number		22	18	17	61
Anamnestic data:					
Male/female		18/4	3/15	1/16	52/9
Mean age (years)		27.5	36.9	36.0	35.6
Heavy alcohol drinker		0	5.6%	0	23.0%
Metallic taste	0/1	0	0	0	4.9%
Excessive salivation	0/1	0	16.7%	5.9%	6.6%
Tremor at work	0/1	0	0	17.6%	11.5%
Sleeping problems	0/1	9.1%	16.7%	52.9%	26.2%
Health problems worsened since Hg exposed	0/1	0	11.1%	64.7%	78.7%

Table 6 (cont.) - Adults from Sulawesi. Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group on a statistically significant level ($p < 0.05$, one-tailed Chi-square test).

Adults from Sulawesi

Data or Test	Value or Score	Control adults	Not occupational burdened	Mineral processors	Amalgam-burners
Case number		22	18	17	61
Anamnestic data:					
Lack of appetite		13.6%	11.1%	17.6%	11.5%
Loss of weight		0	5.6%	5.9%	11.5%
Easily tired		0	5.6%	0	14.8%
Rest more		0	0	0	13.1%
Feel sleepy		0	11.1%	5.9%	13.1%
Problems to start things		0	0	0	4.9%
Lack of energy		0	0	0	14.8%
Less strength		0	0	0	13.1%
Weak		0	5.6%	0	13.1%

Table 6 (cont.) - Adults from Sulawesi. Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group on a statistically significant level ($p < 0.05$, one-tailed Chi-square test).

Adults from Sulawesi

Data or Test	**Value or Score**	**Control adults**	**Not occupational burdened**	**Mineral processors**	**Amalgam-burners**
Case number		22	18	17	61
Anamnestic data:					
Problems with concentration		0	0	5.9%	9.8%
Problems to think clear		0	5.6%	11.8%	4.9%
Word finding problems		0	0	0	8.2%
Eyestrain		0	0	11.8%	6.6%
Memory problems		0	11.1%	17.6%	13.1%
Feel nervous		0	16.7%	29.4%	21.3%
Feel sad		0	16.7%	11.8%	4.9%
Headache		0	38.9%	58.8%	27.9%
Nausea		0	22.2%	47.1%	21.3%
Numbness		4.5%	27.8%	58.8%	37.7%

Table 6 (cont.) - Adults from Sulawesi. Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group on a statistically significant level ($p < 0.05$, one-tailed Chi-square test).

Adults from Sulawesi

Data or Test	**Value or Score**	**Control adults**	**Not occupational burdened**	**Mineral processors**	**Amalgam-burners**
Case number		22	18	17	61
Clinical data:					
Bluish coloration of gingiva	0/1	0	0	5.9%	11.5%
Gingivitis		0	0	0	0
Ataxia of gait	0/1	9.1%	44.4%	23.5%	49.2%
Finger to nose tremor	0/1	9.1%	5.6%	5.9%	1.6%
Finger to nose dysmetria		0	11.1%	0	6.6%
Dysdiadochokin esia	0/1	18.2%	16.7%	29.4%	36.1%
Tremor of eyelid		54.6%	38.9%	23.6%	39.4%

Table 6 (cont.) - Adults from Sulawesi. Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group on a statistically significant level ($p < 0.05$, one-tailed Chi-square test).

Adults from Sulawesi

Data or Test	**Value or Score**	**Control adults**	**Not occupational burdened**	**Mineral processors**	**Amalgam-burners**
Case number		22	18	17	61
Clinical data:					
Horizontal field of vision (median)		170°	164°	159°	164°
Heel to knee ataxia	0/1	0	55.6%	23.5%	31.1%
Heel to knee tremor	0/1	0	0	0	3.3%
PSR normal		54.5%	61.1%	70.6%	59.0%
BSR normal		90.9%	77.8%	70.6%	68.9%
ASR normal		59.1%	50.0%	58.8%	50.8%
Mento-labial reflex pathologic	0/1	36.4%	27.8%	0	16.4%
Bradykinesia		0	11.1%	17.6%	13.1%
Hypomimia		0	5.6%	5.9%	9.8%
Proteinuria	0/1	9.1%	22.2%	0	1.6%

Table 6 (cont.) - Adults from Sulawesi. Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group on a statistically significant level ($p < 0.05$, one-tailed Chi-square test).

Adults from Sulawesi

Data or Test	**Value or Score**	**Control adults**	**Not occupational burdened**	**Mineral processors**	**Amalgam-burners**
Case number		22	18	17	61
Neuro-psychological test					
Memory test	0-1	63.6%	50.0%	23.5%	40.0%
	2	31.8%	27.8%	47.1%	26.7%
	3-4 (worst)	4.5%	22.2%	29.4%	33.3%
Match box test	10-16 sec	63.6%	16.7%	23.5%	21.3%
	17-22 sec	31.8%	50.0%	58.8%	59.0%
	23-45 sec (worst)	4.5%	33.3%	17.6%	19.7%

Table 6 (cont.) - Adults from Sulawesi. Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group on a statistically significant level ($p < 0.05$, one-tailed Chi-square test).

Adults from Sulawesi

Data or Test	**Value or Score**	**Control adults**	**Not occupational burdened**	**Mineral processors**	**Amalgam-burners**
Case number		22	18	17	61
Neuro-psychological test					
Frostig test	13-12	45.5%	22.2%	29.4%	26.2%
	11-10	40.9%	27.8%	29.4%	39.3%
	9-2 (worst)	13.6%	50.0%	41.2%	34.4%
Pencil tapping test	90-63	81.8%	11.1%	23.5%	39.3%
	62-52	18.2%	66.7%	52.9%	41.0%
	51-26 (worst)	0	22.2%	23.5%	19.7%

Table 6 (cont.) - Adults from Sulawesi. Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group on a statistically significant level ($p < 0.05$, one-tailed Chi-square test).

Adults from Sulawesi

Data or Test	Value or Score	Control adults	Not occupational burdened	Mineral processors	Amalgam-burners
Bio-monitoring					
Hg-urine (µg/l)	No.	22	18	17	61
	median	0.7	3.0	7.8	21.9
	> HBM II	0	0	11.8%	44.3%
	> BAT	0	0	0	11.5%
	max.	3.2	18.6	57.6	564
Hg-urine (µg/g creatinine)	No.	22	18	17	61
	median	0.4	2.0	3.7	10.0
	> HBM II	0	0	5.9%	34.4%
	max.	1.35	9.8	23.0	233

Table 6 (cont.) - Adults from Sulawesi. Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group on a statistically significant level ($p < 0.05$, one-tailed Chi-square test).

Adults from Sulawesi

Data or Test	Value or Score	Control adults	Not occupational burdened	Mineral processors	Amalgam-burners
Bio-monitoring					
Hg-blood	No.	21	18	17	61
	median	4.6	6.0	9.2	13.2
	> HBM II	0	0	23.5%	44.3%
	> BAT	0	0	5.9%	24.6%
	max.	10.1	12.6	78.4	186
Total Hg-hair	No.	21	18	17	60
	median	1.52	1.65	2.96	4.79
	> 5 µg/g	0	5.6%	23.5%	48.3%
	max.	3.72	10.3	40.0	239

Table 6 (cont.) - Adults from Sulawesi. Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group on a statistically significant level ($p < 0.05$, one-tailed Chi-square test).

Adults from Sulawesi

Data or Test	**Value or Score**	**Control adults**	**Not occupational burdened**	**Mineral processors**	**Amalgam-burners**
Case number		22	18	17	61
Medical test score	median	2.5	5.5	6.0	6.0
	0-4	90.9%	22.2%	17.6%	18.0%
	5-9	9.1%	61.1%	76.5%	68.9%
	10-21 (worst)	0	16.7%	5.9%	13.1%
HBM II and BAT					
Blood or urine or hair	> HBM II	0	5.6%	29.4%	60.7%
Blood or urine	> BAT	0	0	5.9%	27.9%
Diagnosis					
Hg intoxication	No. (%)	0	2 (11.1%)	4 (23.5%)	33 (54.1%)

Table 7 - Adults from Kalimantan: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi on a statistically significant level ($p < 0.05$, one-tailed Chi-square test)

Adults from Kalimantan

Data or Test	**Sulawesi**		**Kalimantan**				
	Value or Score	**Control adults**	**Tang-kiling**	**Former miner**	**Not occupational burdened**	**Mineral processors**	**Amalgam-burners**
Case number		22	36	10	67	30	69
Anamnestic data:							
Male/female		18/4	3/33	0/10	3/64	15/15	50/19
Mean age (years)		27.5	36.2	36.5	31.4	33.7	31.9
Heavy alcohol drinker		0	0	0	0	0	0
Metallic taste	0/1	0	0	10.0%	22.4%	20.0%	36.2%
Excessive salivation	0/1	0	8.6%	20.0%	9.0%	36.7%	36.2%
Tremor at work	0/1	0	20.0%	30.0%	37.3%	23.3%	37.7%
Sleeping problems	0/1	9.1%	17.1%	30.0%	55.2%	46.7%	37.7%
Health problems worsened since Hg exposed	0/1	0	0	10.0%	3.0%	16.7%	30.4%

Table 7 (cont.) - Adults from Kalimantan: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi on a statistically significant level ($p < 0.05$, one-tailed Chi-square test)

Adults from Kalimantan

Data or Test	Sulawesi		Kalimantan				
	Value or Score	**Control adults**	**Tang-kiling**	**Former miner**	**Not occupational burdened**	**Mineral processors**	**Amalgam-burners**
Case number		22	36	10	67	30	69
Anamnestic data:							
Lack of appetite		13.6%	36.2%	50.0%	70.1%	56.7%	58.0%
Loss of weight		0	61.1%	70.0%	67.2%	73.3%	44.2%
Easily tired		0	47.2%	70.0%	47.8%	56.6%	53.6%
Rest more		0	44.4%	70.0%	38.8%	36.6%	50.7%
Feel sleepy		0	13.9%	30.0%	31.3%	46.7%	39.1%
Problems to start things		0	0	20.0%	1.5%	3.3%	10.1%
Lack of energy		0	25.0%	60.0%	35.8%	53.3%	38.2%
Less strength		0	25.0%	60.0%	38.8%	50.0%	43.5%
Weak		0	25.0%	50.0%	40.3%	50.0%	41.1%

Table 7 (cont.) - Adults from Kalimantan: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi on a statistically significant level ($p < 0.05$, one-tailed Chi-square test)

Adults from Kalimantan

Data or Test	Sulawesi		Kalimantan				
	Value or Score	Control adults	Tang-kiling	Former miner	Not occupational burdened	Mineral processors	Amalgam-burners
Case number		22	36	10	67	30	69
Anamnestic data:							
Problems with concentration		0	11.0%	20.0%	9.0%	10.0%	20.3%
Problems to think clear		0	2.8%	10.0%	3.0%	10.0%	15.9%
Word finding problems		0	5.6%	20.0%	9.0%	10.0%	8.7%
Eyestrain		0	11.1%	20.0%	17.9%	20.0%	26.4%
Memory problems		0	55.5%	70.0%	59.0%	36.7%	46.3%
Feel nervous		0	52.8%	70.0%	59.1%	63.3%	66.1%
Feel sad		0	75.0%	100%	75.8%	76.7%	63.2%
Headache		0	80.0%	90.0%	83.6%	93.1%	81.2%
Nausea		0	47.2%	100%	62.7%	60.0%	60.9%
Numbness		4.5%	66.7%	70.0%	70.1%	73.3%	88.4%

Table 7 (cont.) - Adults from Kalimantan: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi on a statistically significant level (p < 0.05, one-tailed Chi-square test)

Adults from Kalimantan

Data or Test	Sulawesi		Kalimantan				
	Value or Score	**Control adults**	**Tang-kiling**	**Former miner**	**Not occupational burdened**	**Mineral processors**	**Amalgam-burners**
Case number		22	36	10	67	30	69
Clinical data:							
Bluish coloration of gingiva	0/1	0	2.9%	0	7.5%	16.7%	10.1%
Gingivitis	0	0	0	3.0%	0	0	0
Ataxia of gait	0/1	9.1%	17.1%	20.0%	50.7%	33.3%	49.3%
Finger to nose tremor	0/1	9.1%	0	10.0%	7.5%	13.3%	11.6%
Finger to nose dysmetria		0	2.8%	0	9.0%	20.0%	15.9%
Dysdiadochokinesia	0/1	18.2%	11.4%	30.0%	38.8%	43.3%	40.6%
Tremor of eyelid		54.6%	30.6%	60.0%	46.3%	60.0%	66.6%

Table 7 (cont.) - Adults from Kalimantan: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi on a statistically significant level ($p < 0.05$, one-tailed Chi-square test)

Adults from Kalimantan

Data or Test	**Sulawesi**		**Kalimantan**				
	Value or Score	**Control adults**	**Tang-kiling**	**Former miner**	**Not occupational burdened**	**Mineral processors**	**Amalgam-burners**
Case number		22	36	10	67	30	69
Clinical data:							
Horizontal field of vision (median)		170°	159°	165°	150°	149°	153°
Heel to knee ataxia	0/1	0	14.3%	50.0%	37.3%	50.0%	62.3%
Heel to knee tremor	0/1	0	0	0	3.0%	3.3%	2.9%
PSR normal		54.5%	72.2%	50.0%	68.7%	56.7%	46.4%
BSR normal		90.9%	80.6%	90.0%	89.4%	80.0%	76.8%
ASR normal		59.1%	72.2%	60.0%	81.8%	66.7%	56.5%
Mento-labial reflex pathologic	0/1	36.4%	17.1%	20.0%	17.9%	16.7%	18.8%
Bradykinesia		0	2.8%	20.0%	4.5%	20.0%	27.5%
Hypomimia		0	2.8%	20.0%	7.5%	20.0%	26.1%
Proteinuria	0/1	9.1%	8.3%	10.0%	10.4%	10.0%	10.1%

Table 7 (cont.) - Adults from Kalimantan: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi on a statistically significant level ($p < 0.05$, one-tailed Chi-square test)

Adults from Kalimantan

Data or Test	**Sulawesi**		**Kalimantan**				
	Value or Score	**Control adults**	**Tang-kiling**	**Former miner**	**Not occupational burdened**	**Mineral processors**	**Amalgam-burners**
Case number		22	36	10	67	30	69
Neuro-psychological test							
Memory test	0-1	63.6%	26.5%	20.0%	11.9%	13.3%	20.3%
	2	31.8%	26.5%	40.0%	44.8%	46.7%	43.5%
	3-4 (worst)	4.5%	47.1%	40.0%	43.3%	40.0%	36.2%
Match box test	10-16 sec	63.6%	11.4%	10.0%	41.8%	30.0%	18.8%
	17-22 sec	31.8%	40.0%	60.0%	37.3%	50.0%	50.7%
	23-45 sec (worst)	4.5%	48.6%	30.0%	20.9%	20.0%	30.4%

Table 7 (cont.) - Adults from Kalimantan: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi on a statistically significant level ($p < 0.05$, one-tailed Chi-square test)

Adults from Kalimantan

Data or Test	**Sulawesi**		**Kalimantan**				
	Value or Score	**Control adults**	**Tang-kiling**	**Former miner**	**Not occupational burdened**	**Mineral processors**	**Amalgam-burners**
Case number		22	35	10	67	30	69
Neuro-psychological test							
Frostig test	13-12	45.5%	37.1%	20.0%	23.9%	36.7%	30.4%
	11-10	40.9%	37.1%	30.0%	38.8%	33.3%	42.0%
	9-2 (worst)	13.6%	25.7%	50.0%	37.3%	30.0%	27.5%
Pencil tapping test	90-63	81.8%	28.6%	10.0%	14.9%	20.0%	22.1%
	62-52	18.2%	34.3%	60.0%	43.3%	63.3%	55.9%
	51-26 (worst)	0	37.1%	30.0%	41.8%	16.7%	22.1%

Table 7 (cont.) - Adults from Kalimantan: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi on a statistically significant level (p < 0.05, one-tailed Chi-square test)

Adults from Kalimantan

Data or Test	Sulawesi		Kalimantan				
	Value or Score	**Control adults**	**Tang-kiling**	**Former miner**	**Not occupational burdened**	**Mineral processors**	**Amalgam-burners**
Bio-monitoring							
Hg-urine (µg/l)	No.	22	36	10	67	30	69
	median	0.7	1.2	1.7	4.5	5.3	10.2
	> HBM II	0	0	0	9.0%	10.0%	34.8%
	> BAT	0	0	0	1.5%	6.7%	18.8%
	max.	3.2	13.1	9.3	874	788	5,240
Hg-urine (µg/g creatinine)	No.	22	36	10	67	30	69
	median	0.4	0.7	1.5	2.7	3.3	5.3
	> HBM II	0	0	0	3.0%	6.7%	24.6%
	max.	1.35	4.8	2.9	355	261	1,697

Table 7 (cont.) - Adults from Kalimantan: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi on a statistically significant level ($p < 0.05$, one-tailed Chi-square test)

Adults from Kalimantan

Data or Test	Sulawesi		Kalimantan				
	Value or Score	**Control adults**	**Tang-kiling**	**Former miner**	**Not occupational burdened**	**Mineral processors**	**Amalgam-burners**
Bio-monitoring							
Hg-blood	No.	21	36	10	67	30	69
	median	4.6	11.0	12.6	8.5	9.5	10.6
	> HBM II	0	22.2%	20.0%	16.4%	33.3%	40.6%
	> BAT	0	0	0	9.0%	16.7%	23.2%
	max.	10.1	19.5	21.1	172	145	429
Total Hg-hair	No.	21	36	10	67	30	68
	median	1.52	2.74	3.70	2.55	3.83	3.86
	> 5 µg/g	0	8.3%	20.0%	23.9%	26.7%	42.6%
	max.	3.72	7.76	7.26	103	793	225

Table 7 (cont.) - Adults from Kalimantan: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi on a statistically significant level ($p < 0.05$, one-tailed Chi-square test)

Adults from Kalimantan

Data or Test	**Sulawesi**		**Kalimantan**				
	Value or Score	**Control adults**	**Tang-kiling**	**Former miner**	**Not occupational burdened**	**Mineral processors**	**Amalgam-burners**
Case number		22	36	10	67	30	69
Medical test score	median	2.5	5.0	7.0	7.0	6.5	8.0
	0-4	90.9%	30.6%	10.0%	13.4%	20.0%	14.5%
	5-9	9.1%	63.9%	80.0%	64.2%	50.0%	50.7%
	10-21 (worst)	0	5.6%	10.0%	22.4%	30.0%	34.8%
HBM II and BAT							
Blood or urine or hair	> HBM II	0	25.0%	30.0%	29.9%	43.3%	53.6%
Blood or urine	> BAT	0	0	0	9.0%	16.7%	24.6%
Diagnosis							
Hg intoxication	No. (%)	0	8 (22.2%)	4 (40.0%)	23 (34.3%)	13 (43.3%)	41 (59.4%)

Table 8 - Children: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi n a statistically significant level (p < 0.05, one-tailed Chi-square test

Children

Data or Test	**Value or Score**	**Sulawesi**			**Kalimantan**	
		Control children	**Children not working with Hg**	**Children working with Hg**	**Children not working with Hg**	**Children working with Hg**
Case number		31	22	51	27	8
Anamnestic data:						
Male/female		13/18	7/15	34/17	16/11	6/2
Mean age (years)		11.6	10.7	11.8	11.8	12.3
Heavy alcohol drinker		0	0	0	0	0
Metallic taste	0/1	0	0	2.0%	11.1%	12.5%
Excessive salivation	0/1	0	0	5.9%	7.4%	12.5%
Tremor at work	0/1	0	0	0	7.4%	25.0%
Sleeping problems	0/1	3.2%	0	2.0%	14.8%	25.0%
Health problems worsened since Hg exposed	0/1	0	54.5%	76.5%	0	0

Table 8 (cont.) - Children: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi n a statistically significant level (p < 0.05, one-tailed Chi-square test

Children

Data or Test	Value or Score	Sulawesi			Kalimantan	
		Control children	Children not working with Hg	Children working with Hg	Children not working with Hg	Children working with Hg
Case number		31	22	51	27	8
Anamnestic data:						
Lack of appetite		0	0	2.0%	51.9%	25.0%
Loss of weight		0	0	0	29.6%	62.5%
Easily tired		0	0	0	14.8%	12.5%
Rest more		0	0	0	11.1%	12.5%
Feel sleepy		0	0	0	7.7%	25.0%
Problems to start things		0	0	0	0	12.5%
Lack of energy		0	0	0	3.7%	0
Less strength		0	0	0	3.7%	0
Weak		0	0	0	3.7%	0

Table 8 (cont.) - Children: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi n a statistically significant level (p < 0.05, one-tailed Chi-square test

Children

Data or Test	Value or Score	Sulawesi			Kalimantan	
		Control children	Children not working with Hg	Children working with Hg	Children not working with Hg	Children working with Hg
Case number		31	22	51	27	8
Anamnestic data:						
Problems with concentration		0	0	0	3.7%	0
Problems to think clear		0	0	0	0	12.5%
Word finding problems		0	0	0	11.5%	0
Eyestrain		0	0	0	0	0
Memory problems		0	0	0	22.2%	71.4%
Feel nervous		3.2%	0	9.8%	77.8%	75.0%
Feel sad		0	0	3.9%	63.0%	75.0%
Headache		19.4%	0	2.0%	76.9%	87.5%
Nausea		0	4.5%	2.0%	25.9%	75.0%
Numbness		3.2%	4.5%	13.7%	7.4%	50.0%

Table 8 (cont.) - Children: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi n a statistically significant level (p < 0.05, one-tailed Chi-square test

Children

Data or Test	**Value or Score**	**Sulawesi**			**Kalimantan**	
		Control children	**Children not working with Hg**	**Children working with Hg**	**Children not working with Hg**	**Children working with Hg**
Case number		31	22	51	27	8
Clinical data:						
Bluish coloration of gingiva	0/1	0	0	2.0%	0	0
Gingivitis	0	0	0	0	0	0
Ataxia of gait	0/1	6.5%	13.6%	29.4%	18.5%	25.0%
Finger to nose tremor	0/1	0	13.6%	5.9%	0	0
Finger to nose dysmetria		0	4.5%	5.9%	7.4%	0
Dysdiadochokinesia	0/1	9.7%	22.7%	29.4%	33.3%	25.0%
Tremor of eyelid		38.7%	40.9%	47.1%	44.4%	50.0%

Table 8 (cont.) - Children: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi n a statistically significant level (p < 0.05, one-tailed Chi-square test

Children

Data or Test	Value or Score	Sulawesi			Kalimantan	
		Control children	Children not working with Hg	Children working with Hg	Children not working with Hg	Children working with Hg
Case number		31	22	51	27	8
Clinical data:						
Horizontal field of vision (median)		173°	173°	172°	169°	167°
Heel to knee ataxia	0/1	12.9%	18.2%	33.3%	48.1%	37.5%
Heel to knee tremor	0/1	0	0	2.0%	0	0
PSR normal		100%	81.8%	84.3%	74.1%	62.5%
BSR normal		93.5%	81.8%	80.4%	85.2%	87.5%
ASR normal		87.1%	81.8%	76.5%	63.0%	50.0%
Mento-labial reflex pathologic	0/1	16.1%	9.1%	15.7%	7.4%	12.5%
Bradykinesia		0	0	0	0	12.5%
Hypomimia		0	0	0	3.7%	0
Proteinuria	0/1	9.7%	9.1%	0	11.1%	12.5%

Table 8 (cont.) - Children: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi n a statistically significant level (p < 0.05, one-tailed Chi-square test

Children

Data or Test	Value or Score	Sulawesi			Kalimantan	
		Control children	Children not working with Hg	Children working with Hg	Children not working with Hg	Children working with Hg
Case number		31	22	51	27	8
Neuro-psychological test						
Memory test	0-1	54.8%	68.2%	47.1%	29.6%	12.5%
	2	25.8%	18.2%	31.4%	51.9%	62.5%
	3-4 (worst)	19.4%	13.6%	21.6%	18.5%	25.0%
Match box test	10-16 sec	71.0%	18.2%	25.5%	14.8%	12.5%
	17-22 sec	29.0%	54.5%	52.9%	40.7%	62.5%
	23-45 sec (worst)	0%	27.3%	21.6%	44.4%	25.0%

Table 8 (cont.) - Children: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi n a statistically significant level ($p < 0.05$, one-tailed Chi-square test

Children

Data or Test	Value or Score	Sulawesi			Kalimantan	
		Control children	Children not working with Hg	Children working with Hg	Children not working with Hg	Children working with Hg
Case number		31	22	51	27	8
Neuro-psychological test						
Frostig test	13-12	67.7%	27.3%	39.2%	44.4%	62.5%
	11-10	29.0%	50.0%	49.0%	44.4%	12.5%
	9-2 (worst)	3.2%	22.7%	11.8%	11.1%	25.0%
Pencil tapping test	90-63	41.9%	4.5%	21.6%	0	12.5%
	62-52	54.8%	45.5%	52.9%	63.0%	50.0%
	51-26 (worst)	3.2%	50.0%	25.5%	37.0%	37.5%

Table 8 (cont.) - Children: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi n a statistically significant level (p < 0.05, one-tailed Chi-square test

Children

Data or Test	Value or Score	Sulawesi			Kalimantan	
		Control children	Children not working with Hg	Children working with Hg	Children not working with Hg	Children working with Hg
Bio-monitoring						
Hg-urine (µg/l)	No.	31	22	51	27	8
	median	0.8	4.2	10.2	4.5	4.6
	> HBM II	0	0	9.8%	7.4%	12.5%
	> BAT	0	0	0	0	12.5%
	max.	2.2	15.0	39.1	29.1	330
Hg-urine (µg/g creatinine)	No.	31	22	51	27	8
	median	0.5	2.6	3.6	3.0	2.8
	> HBM II	0	0	3.9%	0	12.5%
	max.	1.0	13.3	25.3	15.3	120.0

Table 8 (cont.) - Children: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi n a statistically significant level (p < 0.05, one-tailed Chi-square test

Children

Data or Test	Value or Score	Sulawesi			Kalimantan	
		Control children	Children not working with Hg	Children working with Hg	Children not working with Hg	Children working with Hg
Bio-monitoring						
Hg-blood	No.	31	22	51	27	8
	median	4.1	5.4	7.8	7.1	8.5
	> HBM II	0	0	13.7%	7.4%	25.0%
	> BAT	0	0	2.0%	0	12.5%
	max.	7.9	12.4	28.4	16.4	64.8
Total Hg-hair	No.	31	22	50	27	8
	median	1.24	2.23	2.16	2.75	2.58
	> 5 µg/g	0	0	4.0%	25.9%	25.0%
	max.	3.46	4.16	6.67	28.1	21.6

Table 8 (cont.) - Children: Relevant data of the sub-groups. Grey shaded fields in the table contain results that differ from the control group from Sulawesi n a statistically significant level (p < 0.05, one-tailed Chi-square test

Children

Data or Test	**Value or Score**	**Sulawesi**			**Kalimantan**	
		Control children	**Children not working with Hg**	**Children working with Hg**	**Children not working with Hg**	**Children working with Hg**
Case number		31	22	51	27	8
Medical test score	median	2.0	5.5	5.0	6.0	6.0
	0-4	87.1%	27.3%	39.2%	22.2%	25.0%
	5-9	12.9%	72.7%	56.9%	77.8%	62.5%
	10-21 (worst)	0	0	3.9%	0	12.5%
HBM II and BAT						
Blood or urine or hair	> HBM II	0	0	21.6%	29.6%	25.0%
Blood or urine	> BAT	0	0	2.0%	0	12.5%
Diagnosis						
Hg intoxication	No. (%)	0	0	9 (17.6%)	5 (18.5%)	2 (25.0%)

Appendix 2

Health Assessment Questionnaire

Health Assessment Questionnaire

by Dr. Stephan Boese O'Reilly, Prof. Dr. Gustav Drasch, Stefan Maydl, Dr. Milan Vosko
Ludwig-Maximilians University, Munich, Germany.
and Dr. Claude Casellas, Prof. Dr. André Rambaud
University of Montpellier, France
Marcello Veiga, UNIDO Vienna, Austria

Removal of Barriers to the Introduction of Cleaner Artisanal Gold Mining and Extraction Technologies
United Nations Industrial Development Organization (UNIDO)
Global Environment Facility (GEF)
United Nations Development Programme (UNDP)
Health Assessment

Name: ____

I hereby declare that I want to take part in the UNIDO project. I will be questioned about my living circumstances and health problems related to mercury. I will be medically examined including neurological examination. Blood, urine and a small amount of hair will be taken. The … will inform me after the laboratory analysis about my personal results. The UNIDO and the … will get the results in a form where my name can not be identified. The assessment is done respecting the "Recommendation for Conduct of Clinical Research" (World Health Organization Declaration of Helsinki).

>>translation<<

Local and Date: ____________________   ______________________________
Signature
(*in case of children signature of parents/guardian*)

Witnesses (if needed):

______________________________ and ______________________________
(Name): (Name):

Personal Data

Participant ID Number: ______________________

Family Name: ………...

Surname:……………………..

First Name:………...

Date of Birth: ....……………………………………..

Age: ....(years)

Gender:

- ☐ 0 Female
- ☐ 1 Male

Address: …………………...
……………………………...

(if possible local codes, like settlement A,B, C ….)

Any telephone for contact: ....

General Questionnaire

Date of interview:........................…………………………………….

Name of the interviewer for this section:..

Code of the interviewer ___________
(please give every interviewer a code, like A,B,C)

Work Exposure

How long have you been living in this area? ______ year(s)

Occupation (Detailed description of the job)

- A ☐ Miner
- B ☐ Mineral processor (in charge of amalgamation)
- C ☐ Gold smelter (gold buyer)
- D ☐ Worker at a cyanidation plant
- E ☐ Farmer
- F ☐ Office Job
- G ☐ Driver
- H ☐ School child (not working)
- J ☐ Other job...…

Have you ever worked in the ______________ area?

0 ____ No

1 ____ Yes

If yes, for how many _______ year(s)?

Have you ever worked as a miner with direct contact with mercury?

0 ____ No

1 ____ Yes

If from when to when: ____________________________________

= _______ years of mercury contact

Have you ever worked burning amalgam or melting gold?

0 ____ No

1 ____ Yes

If yes, from when to when: ________________________________

= _______ years of mercury contact

Have you been using retort?

0 ____ Yes

1 ____ No

Have you stored mercury containers or flasks?

0 ____ Never

1 ____ At work

2 ____ At home

Have you kept your dirty working clothes at your home?

0 ____ No

1 ____ Yes

For how many years have you been working with mercury?

0 ____ not applicable (have not working directly with mercury)

1 ____ year(s)

Diet Issues

Fish eating habits

How frequently do you eat fish?

0 ____ Never

1 ____ At least once a month

2. ____ At least once a week

3. ____ At least once a day

How much fish to you eat?

________ meals per day

or

________ meals per week

Name the two or three types of fish you consume regularly. If possible, indicate the type of fish that you eat the most:

- Does this fish eat other fish?
- Does this fish eat insects or small bugs?
- Does this fish eat plants or feed on the bottom?

List the species you most often eat. . If possible, try to estimate this between wet season and dry season.

Use a number to estimate how often you eat each species:

4 = most meals; 3 = about half the meals; 2 = some meals 1 = occasionally.

Fish Name	Species	% (dry season)	% (wet season)
__________________________	____	____	____
__________________________	____	____	____
__________________________	____	____	____
__________________________	____	____	____
__________________________	____	____	____
__________________________	____	____	____
__________________________	____	____	____
__________________________	____	____	____
__________________________	____	____	____

The more detailed the information an individual can provide on his/her fish consumption, the better. It is important to instruct health care workers delivering the questionnaire on this. At the very least you must determine: the number of meals, type of fish consumed and amount of fish (e.g., the size of you fist? the size of your hand? Etc) consumed; daily, weekly or monthly as appropriate (in some seasons, fish may not be consumed).

Please code the fishes like A, B, D, E, F, (Please use useful list of fish according to local habits)

Do you know where the fish come from?

0 _____ from areas distant from mining

1 _____ from areas impacted by mining

9 _____ don’t know the origin of the fish (buy in the market)

Can you name the river and local where you catch most fish you have consumed?

A ____ No

B____ Yes, the river (or lake or pool) is ______________________________

(Please give the areas codes, like C, D, E, F …)

Other dietary issues

Name the place where you obtain drinking water:

____

(Please give the areas codes, like C, D, E, F …)

Do you consume from local production chicken, ducks or eggs?

0 ____ Never

1 ____ At least once a month

2 ____ At least once a week

3 ____ At least once a day

Do you consume from local production meat?

0 ____ Never

1 ____ At least once a month

2 ____ At least once a week

3 ____ At least once a day

Do you consume from local production vegetables, fruits?

0 ____ Never

1 ____ At least once a month

2 ____ At least once a week

3 ____ At least once a day

Confounders

Do you smoke?

0 ____ Never

1 ____ Rarely (0-10 cigarettes per day)

2 ____ Medium (10-20 cigarettes per day)

3 ____ Lots (more then 20 cigarettes per day)

Do you drink alcohol?

0 ____ Never

1 ____ at least once a month

2 ____ at least once a week

3 ____ at least once a day

Have you been constantly handling gasoline and kerosene?

0 ____ No

1 ____ Yes

If yes, how many years you have been doing this? ______ (years)

Have you been constantly handling insecticides or pesticides?

0 ____ No

1 ____ Yes

If yes, how many years you have been doing this? ______ (years)

Do you use whitening soap (for lightening the skin)?

0 ____ No

1 ____ Yes

How is your current financial situation?

0 ____ ☺ (OK)

1 ____ 😐 (medium)

2 ____ ☹ (bad)

How is your current social life? (friends, family, hobby activities, etc.)

0 ____ ☺ (OK)

1 ____ 😐 (medium)

2 ____ ☹ (bad)

Health Problems not related to mercury

Date of interview:..

Name of the interviewer for this section:..

Code of the interviewer ____________________
(please give every interviewer a code, like A,B,C)

Are you healthy now?

0 ____ Yes

1 ____ No

Why not? ____

Do you have fever at the moment?

0 ____ No

1 ____ Yes

Did you loose weight within the last year?

0 ____ No

1 ____ Yes

Did you cough within the last year for more then for 3 month?

0 ____ No

1 ____ Yes

Have you ever had malaria?

0 ____ No

1 ____ Yes

If yes, how many time ago you had your last malaria? _______ (days or weeks or months or years)

Have you ever had sleeping sickness? (for Africa)

0 ____ No

1 ____ Yes

Have you ever had any other major infectious disease?

0 ____ No

1 ____ Yes

Which disease (problem)? ____

Have you ever had kidney disease except urinary tract infection?

0 ____ No

1 ____ Yes

Which disease (problem)? ____

Which disease (problem)? ____

Have you ever had hepatitis or any other hepatic disorder?

0 ____ No

1 ____ Yes

Which disease (problem)? ____

Have you ever had severe respiratory problems (asthma, pneumonia)?

0 ____ No

1 ____ Yes

Which disease (problem)? ____

Did you ever have tuberculosis?

0 ____ No

1 ____ Yes

When did this happen ? _______________ (days or weeks or months or years) ago

Have you ever had any neurological disorders (epilepsy, stroke, Parkinson etc.) or mental disorders?

0 ____ No

1 ____ Yes

Which disease (problem)? ____

Did you have any serious accidents (did you have to go to hospital)?

0 ____ No

1 ____ Yes, but not severe (less then 1 hour unconsciousness)

2 ___ Yes, and it was severe (more then 1 hour unconsciousness)

When did this happen ? _______________ (days or weeks or months or years) ago

Exclusion criteria from statistical evaluation

Severe neurological disease such as Parkinson, stroke or severe accident (brain injury), birth trauma, tetanus, polio, diabetes, hyperthyroidism or any acute severe disease, etc...

To be filled in by project doctor.

0 ____ No

1 ____ Yes

Why this individual should be excluded from the assessment:

____

____

Health Questions related to mercury exposure

Date of interview:..........................……………………………….

Name of the interviewer for this section:.....................................……………………………

Code of the interviewer ___________
(please give every interviewer a code, like A,B,C)

Has the actual or former health problem worsened since exposure to mercury occurred?

0 _____ No mercury exposure

1 _____ Mercury exposure, but no worsening effects

2 ____ Yes, mercury exposure and worsening

How is your appetite?

0 ____ ☺ (OK)

1 ____ 😐 (medium)

2 ____ ☹ (bad)

Did you loose hair within the last year?

0 ____ No or only rarely

1 ____ Yes, slight to moderate

2 ____ Yes, marked to sever

Sleep disturbances

How do you feel after a usual night of sleep?

0 ____ ☺ (OK)

1 ____ 😐 (medium)

2 ____ ☹ (bad)

Do you feel a kind of a metallic taste?

0 ____ Never

1 ____ at least once a month

2 ____ at least once a week

3 ____ at least once a day

Do you suffer from excessive salivation?

0 ____ Never

1 ____ at least once a month

2 ____ at least once a week

3 ____ at least once a day

Have you had any problems with tremor (shaking)?

(Clinical Tremor Rating Scale)

0 ____ I have no tremor or tremor does not interfere with my job

1 ____ I am able to work, but I need to be more careful than the average person

2 ____ I am able to do everything, but with errors; poorer than usual performance because of tremor

3 ____ I am unable to do a regular job, I may have changed to a different job due to tremor; it limits some housework, such as ironing

4 ____ I am unable to do any outside job; housework very limited

Fatigue

Score to estimate the state of fatigue (Wessely S, Powell R: Fatigue syndrome)

Have you got tired easily?

0 ____ Same as usual

1 ____ Worse then usual

2 ____ Much worse than usual

Do you need to rest more?

0 ____ Same as usual

1 ____ Worse then usual

2 ____ Much worse than usual

Do you feel sleepy or drowsy?

0 ____ Same as usual

1 ____ Worse then usual

2 ____ Much worse than usual

Can you no longer start anything?

0 ____ Same as usual

1 ____ Worse then usual

2 ____ Much worse than usual

Do you always lack energy?

0 ____ Same as usual

1 ____ Worse then usual

2 ____ Much worse than usual

Do you have less strength in your muscles?

0 ____ Same as usual

1 ____ Worse then usual

2 ____ Much worse than usual

Do you feel weak?

0 ____ Same as usual

1 ____ Worse then usual

2 ____ Much worse than usual

Can you start things without difficulties, but get weak as you go on?

0 ____ Same as usual

1 ____ Worse then usual

2 ____ Much worse than usual

Physical fatigue sum: ____________ score sum (0 to 0)

Do you have problems concentrating?

0 ____ Same as usual

1 ____ Worse then usual

2 ____ Much worse than usual

Do you have problems thinking clearly?

0 ____ Same as usual

1 ____ Worse then usual

2 ____ Much worse than usual

Do you have problems to find correct words when you speak?

0 ____ Same as usual

1 ____ Worse then usual

2 ____ Much worse than usual

Do you have problems with eyestrain?

0 ____ Same as usual

1 ____ Worse then usual

2 ____ Much worse than usual

Do you have problems with memory?

0 ____ Same as usual

1 ____ Worse then usual

2 ____ Much worse than usual

Mental fatigue sum: ____________ score sum (0 to 0)

Well being

Do you feel nervous?

0 ____ Never

1 ____ at least once a month

2 ____ at least once a week

3 ____ at least once a day

Do you feel sad?

0 ____ Never

1 ____ at least once a month

2 ____ at least once a week

3 ____ at least once a day

Do you have palpitations?

Feeling the heart beating

0 ____ Never

1 ____ at least once a month

2 ____ at least once a week

3 ____ at least once a day

Do you have a headache?

0 ____ Never

1 ____ at least once a month

2 ____ at least once a week

3 ____ at least once a day

Do you have nausea?

0 ____ Never

1 ____ at least once a month

2 ____ at least once a week

3 ____ at least once a day

Do you feel numbness, prickling, aching at any location of your body?

Mainly perioral dysesthesia and sensory impairment of the glove and-stocking type

0 ____ Never

1 ____ at least once a month

2 ____ at least once a week

3 ____ at least once a day

Clinical – neurological examination

Date of neurological examination:.........................……………………………………

Name of the neurological examiner:...................................…………………………..

Code of the examiner ___________
(please give every examiner a code, like N,O,P)

Mouth and Teeth Conditions

Clinical signs of stomatitis

0 ____ No

1 ____ Yes

Clinical signs of gingivitis

0 ____ No

1 ____ Yes

Bluish discoloration of the gums

0 ____ No

1 ____ Slight

2 ____ Yes, obvious

How many teeth with dental fillings (Amalgam)?

0 ____ None

(n) ___ One or more → how many _______

Examination of the eyes:

0 _____ No changes

1 _____ Bluish colored iris ring

2 _____ Kayser-Fleischer ring

Walking

Person is asked to walk up and down, first with eyes open, then with eyes closed.

Ataxia of gait (walking)

Examiner is watching for signs of ataxia (Klockgether Score p 435)

0 ___ Absent

1 ___ Slight (ataxia only visible when walking on tandem or without visual feedback)

2 ___ Moderate (ataxia visible in normal walking; difficulties, when walking on tandem)

3 ___ Marked (broad-based, staggering gait; unable to walk on tandem)

4 ___ Severe (unable to walk without support; wheelchair bound)

5 ___ Most severe (bedridden)

Rigidity of gait (walking)

Examiner is watching the gait, the swing of the arms, general posture and rates

0 ____ Normal

1 ____ Mild diminution in swing while the patient is walking

2 ____ Obvious diminution in swing suggesting shoulder rigidity

3 ____ Stiff gait with little or no arm swinging noticeable

4 ____ Rigid gait with arms slightly pronated; this would also include stopped-shuffling gait with propulsion and retropulsion

Standing

Tremor - finger to nose test

Person is asked to stand still, legs together– arms outstretched. Eyes closed. Finger tip should touch the nose. Examiner is watching and rates the tremor (modified Clinical Tremor Rating Scale)

0 ____ None

1 ____ Slight to moderate (amplitude < 0,5 cm – 1cm); may be intermittent, may be intermittent

2 ____ Marked amplitude (1-2 cm)

3 ____ Severe amplitude (> 2 cm)

Dysmetria - finger to nose test

Person is asked to stand still, legs together – arms outstretched. Eyes closed. Finger tip should touch the nose. Examiner is watching and rates the dysmetria

0 ____ Normal

1 ____ Moderate pathologic

2 ____ Severe pathologic

Dysdiadochokinesis

Person is asked to twist hands very quickly (alternating movements of the wrists (Klockgether Score)

0 ____ Absent

1 ____ Slight (minimal slowness of alternating movements)

2 ____ Moderate (marked slowness of alternating movements)

3 ____ Severe (severe irregularity of alternating movements)

4 ____ Most severe (inability to perform alternating movements)

Tremor – eye lid

Eyes closed. Examiner is watching and rates the tremor (Davao Pool score)

0 ____ None

1 ____ Slight

2 ____ Marked

Lying - Reflexes

Person is asked to lie on the examination bench.

Mentolabial reflex (Positive pyramidal sign)

0 ____ Negative

1 ____ Positive

Babinski reflex (Positive pyramidal signs)

0 ____ Negative

1 ____ Positive

Sucking reflex (Positive pyramidal signs)

0 ____ Negative

1 ____ Positive

Grasp reflex

0 ____ Negative

1 ____ Positive

PSR (quadrizeps reflex)

A No reflex

B Hyporeflexia

C Normal

D Hyperreflexia

E Clonus

BSR (bizeps brachii reflex)

A No reflex

B Hyporeflexia

C Normal

D Hyperreflexia

E Clonus

AR (Achilles reflex, ankle jerk)

A No reflex

B Hyporeflexia

C Normal

D Hyperreflexia

E Clonus

Lying – other tests

Intentional Tremor - heel-to-shin test

Person is asked to touch with his heel the knee of the other leg. Then to move with the heel along the shin to the foot. Repeat and do it with both sides. Eyes first open, then closed. Rate tremor during heel-to-shin test (Klockgether Score)

0 ____ Absent

1 ____ Slight (slight terminal tremor)

2 ____ Moderate (marked terminal tremor)

3 ____ Marked (kinetic tremor throughout intended movements)

4 ____ Severe (severe kinetic tremor heavily interfering with everyday life)

5 ____ Most severe (maximal form of kinetic tremor making intended movements impossible)

Ataxia - heel-to-shin test

Rate ataxia (Klockgether Score)

0 ____ Absent

1 ____ Slight (slight hypermetria in heel-to-shin test)

2 ____ Moderate (hypermetria and slight ataxic performance of heel-to-shin test)

3 ____ Marked (marked swaying: unable to stand with feet together)

4 ____ Severe (pronounced ataxia in performing heel-to-shin test)

5 ____ Most severe (unable to perform heel-to-shin test)

Sensory disturbances

Sensory disturbances such as sensory impairment of the glove and-stocking type

0 ____ Absent

1 ____ Present

Comments____

____

Bradykinesia

Rate your observation whether there was any sign of bradykinesia during the examination (slower active movements, absent or altered synkinesia of upper extremities during gait)

0 ____ Absent

1 ____ Present

Hypo-mimia

Rate your observation whether there you observed an hypo mimic expression of the face during the examination)

0 ____ Absent

1 ____ Present

Specific Tests

Date of the specific test:........................…………………………………………….

Name of the tester:....................................…………………………………………

Code of the tester ___________

(please give every examiner a code, like N,O,P)

Memory Disturbances (Wechsler)

Forward digit span test (part of *Wechsler Memory Scale)*

Please repeat each column of numbers. Score longest series correctly repeated forward

	Score	Test
	4	6-4-3-9
	4	7-2-8-6
	3	4-2-7-3-1
	3	7-5-8-3-6
	2	6-1-9-4-7-3
	2	3-9-2-4-8-7
	1	5-9-1-7-4-2-3
	1	4-1-7-9-3-8-6
	0	5-8-1-9-2-6-4-7
	0	3-8-2-9-5-1-7-4

Match Box Test (from *MOT*)

Put 20 matches on a table , half of each on one side of an open matchbox, approx. 15 cm away. Take the time until all matches are put into the box. Use left and right hand alternatively.

_______ seconds

Finger Tapping Test (from *MOT*)

Sitting at a table. Elbows should be placed on the table. Try to do as many points as possible on a piece of paper with a pencil. Count the amount of points within 10 seconds.

________ points

Frostig Score

Draw a line from one symbol to the other. Do not interrupt while drawing. Do not touch the lines.

Score: _______

Please connect with a pencil the symbols. Please try to stay within the lines. ??

F1✏ ✈

0-2

F2 ✏ ✈

0-2

F3 ✎ ✈

0-2

F4 ✎ ✈

0-1

F5 ✎ ✈

0-2

F6 ✎ ✈

0-2

Please connect the symbols with a straight line.

F7 ☸ ☸

F8 ☸ ☸

0-1

Memory Disturbances (new battery)

Orientation to time - season
0____ correct response
1____ incorrect response

Orientation to time- part of the day
0____ correct response
1____ incorrect response

Orientation to place – name of the village
0____ correct response
1____ incorrect response

Orientation to place – name of the country
0____ correct response
1____ incorrect response

Episodic memory (registration of 3 words): example: fish, ball, tree

0 ____ Registered all 3

1 ____ Registered jus t 2

2 ____ Registered just 1

3 ____ Registered none

Visual field test

Result ______________________

Objective tremor assessment

Result __________________________

Specimens

Date of the specimen...

Time of the specimen sampling..

Name of the specimen taker:...

Code ___________

Blood (EDTA-blood 10 ml)

____ Yes

____ No

Urine (spontaneous urine sample 10 ml)

____ Yes

____ No

Proteinuria

0 ____ negative

1 ____ positive ____ score

Urine total mercury (field test) (additional)

____ Result ____ unit

Hair

____ Yes, sample collected

____ No

Others (breast milk)

____ Yes, sample collected

____ No sample

Laboratory Analysis Results

Material/test

Result Unit

Blood

Total mercury

______ μg/l

Methyl-mercury

______ μg/l

Selenium

______ μg/l

Urine

Total mercury

______ μg/l

Total mercury / g crea

______ μg / g crea

Methyl mercury

______ μg/l

Methyl mercury / g crea

______ μg/ g crea

Hair

Total mercury

______ μg / g

Methyl mercury

______ μg / g

Others (breast milk)

Total mercury

______ μg/l

Comments:

____

____

____

____

____

____

Medical Score Sum

Test	**Score Points**	**Results**
Anamnestic data		
Metallic taste (see 0)	0/1	
Excessive salivation (see 0)	0/1	
Tremor at work (see 0)	0/1	
Sleeping problems at night (see 0)	0/1	
Health problems worsened since Hg exposed (see 0)	0/1	
Clinical data		
Bluish coloration of gingiva (see 0)	0/1	
Ataxia of gait (see 0)	0/1	
Finger to nose trem (see 0)or	0/1	
Dysdiadochokinesis (see 0)	0/1	
Heel to knee ataxia (see 0)	0/1	
Heel to knee tremor (see 0)	0/1	
Mento labial reflex (see 0)	0/1	
Proteinuria (see 0) [1]	0/1	
Neuropsychological tests		
Memory test (see 0) [2]	0/1/2	
Matchbox test (see 0) [3]	0/1/2	
Frostig test (see 0) [4]	0/1/2	
Tapping test (see 0) [5]	0/1/2	
Maximum	21	

Medical score sum ______________

[1] Proteinuria 1 = more then trace, 0 = 0 or

[2] Memory test: 2 = score 0, 1 = score 1-2, 0 = score 3-4

[3] Matchbox test: 2 = 21 seconds or more, 1 = 16-20 seconds, 0 = 0-15 seconds

[4] Frostig test: 2 = 0-9 correct answers, 1 = 10-12 correct answers, 0 = 13-16 correct answers

[5] Tapping test: 2 = 0-53 dots, 1= 54-64 dots, 0 = 65 or more dots

Decision for the diagnosis of a “chronic mercury intoxication”

Threshold limits for mercury

Table 9 - Toxicologically established threshold limits for mercury in blood, urine and hair (HBM = Human Bio-Monitoring; BAT = Biologischer Arbeitsstoff-Toleranzwert; BEI = Biological Exposure Indices)

	Hg-blood (µg/l)	Hg-urine (µg/l)	Hg-urine (µg/g crea)	Hg-hair (µg/g)
HBM I	5	7	5	
HBM II	15	25	20	5 (in analogy)
WHO		50		7
BAT for metallic and inorganic Hg	25	100		
BAT for organic Hg	100			
BEI (Biological exposure index)	15 (after working)		35 (before working)	

Decision for the diagnosis of a “chronic mercury intoxication”

Table 10 - Decision for the diagnosis “chronic mercury intoxication” Intoxication

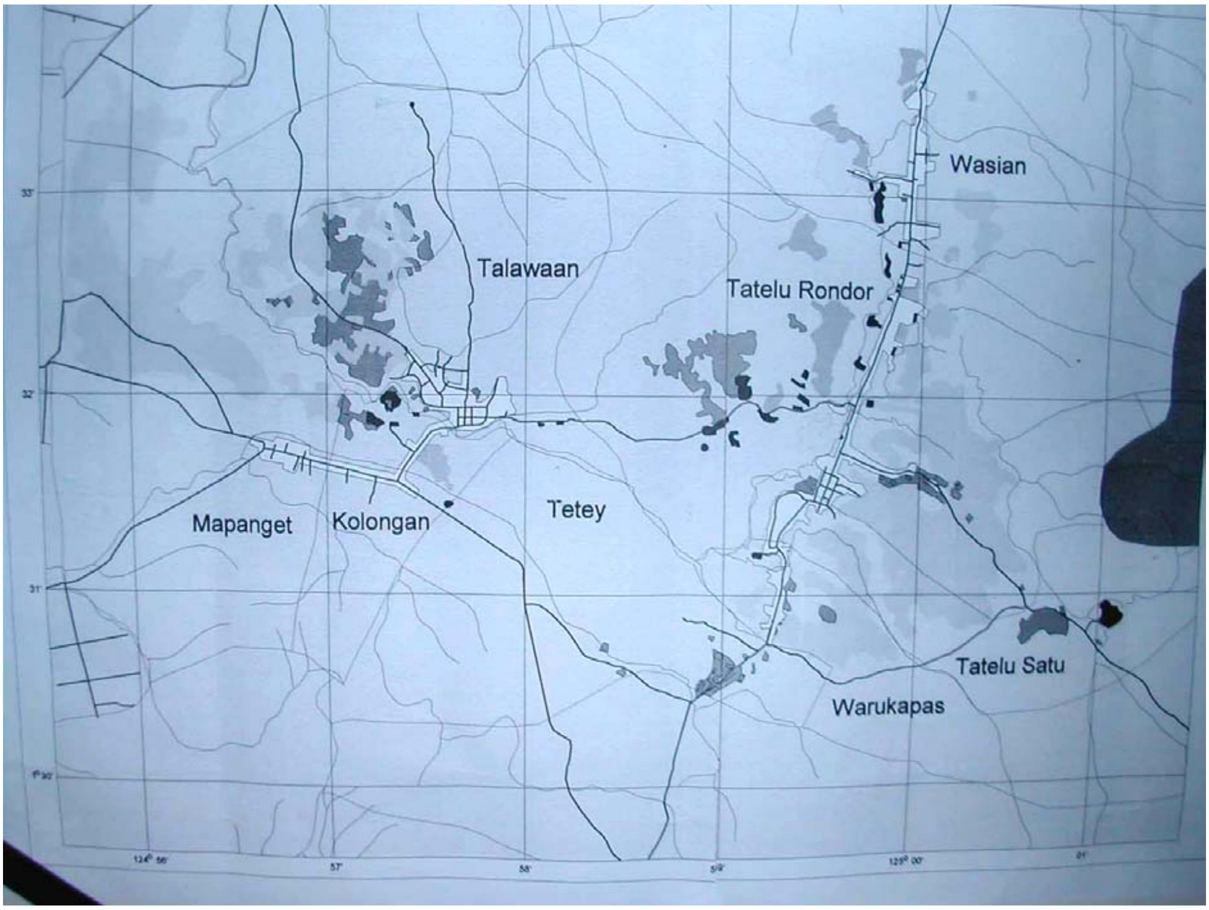
		Medical Score Sum		
		0 – 4	5 – 9	10 - 19
Hg in all biomonitors	< HBM I	–	–	–
Hg at least in one biomonitor	> HBM I	–	–	+
	> HBM II	–	+	+
	> BAT	+	+	+

________ no

________ yes

Appendix 3

Pictures

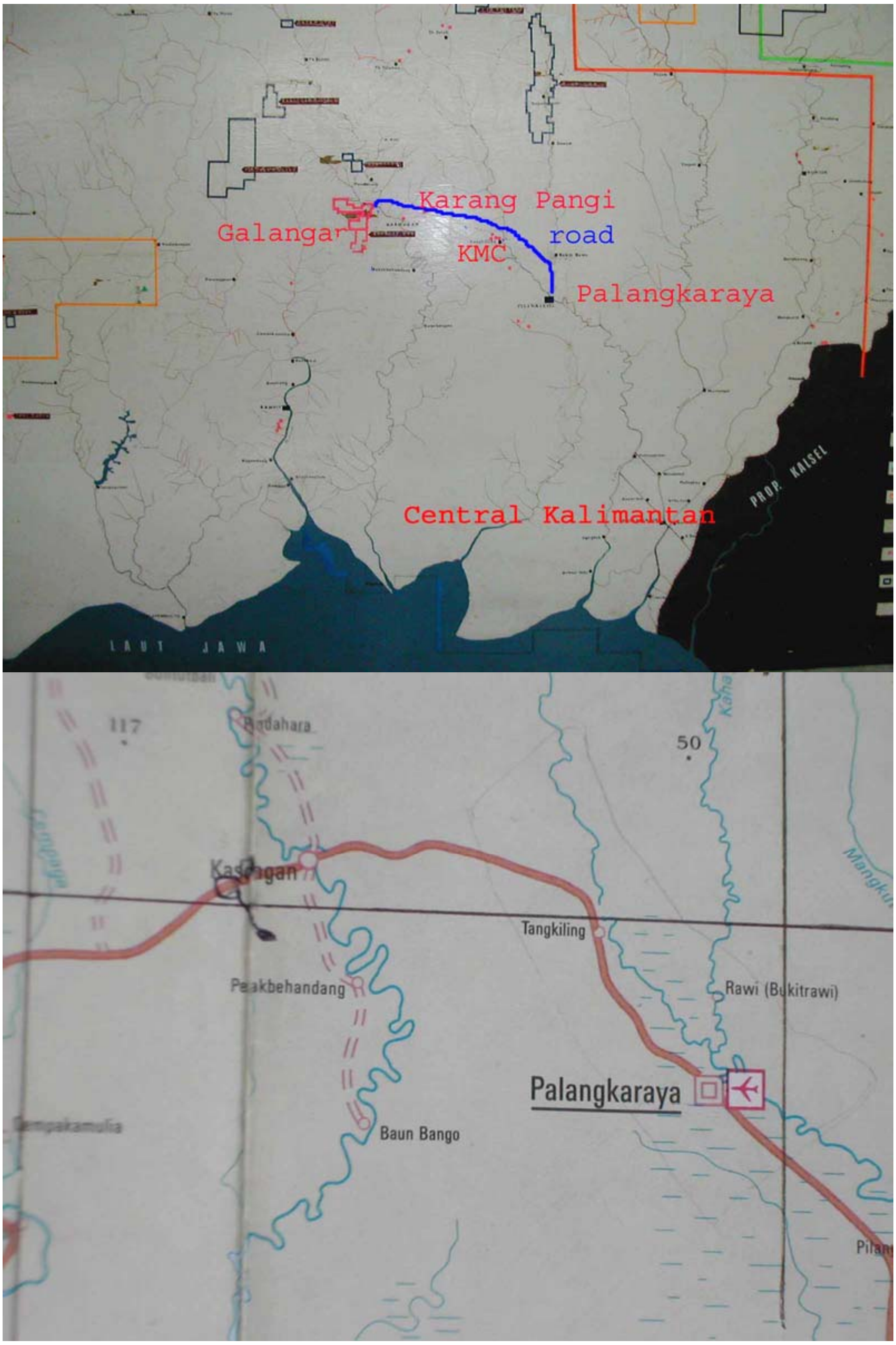


Map of Tatelu area

Manado Bay

Manado Bay

Village centre in Tatelu, where the health assessment was performed



Map of Central Kalimantan, KMC = Tangkiling, no mining area upstream is recorded.
Tangkiling is situated on a different river system to Galangan area

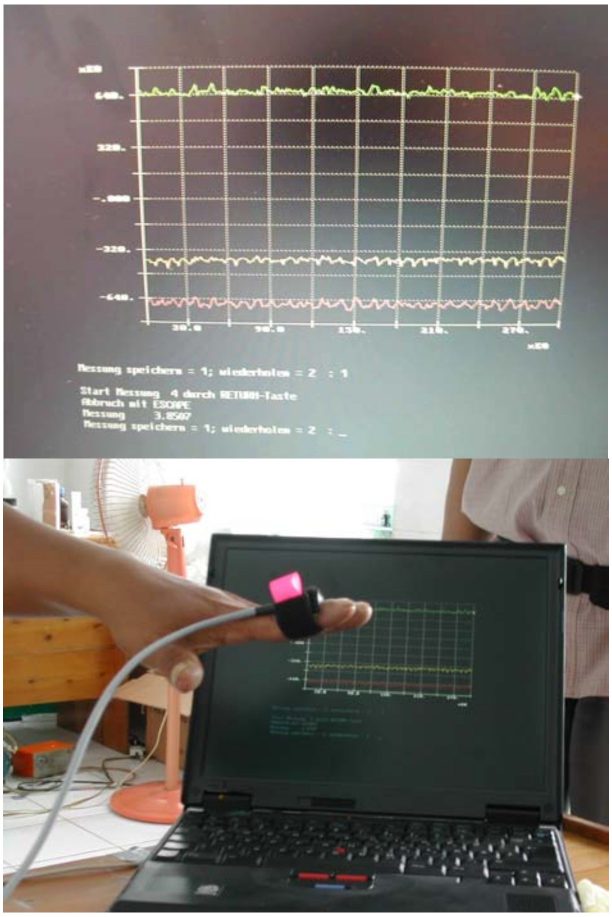
Local health centre in Kereng Pangi

Local health team members in Kereng Pangi

Performing the questionnaire

Performing the test for dysdiadochokinesia

Pencil tapping test



Tremor-meter

Mobile mercury analyzer

Open pit mining in Galangan (Kalimantan) Sulawesi – Manado Bay

Amalgam smelting place in a small shop in the Galangan area (Kalimantan)

Amalgam smelting in Kereng Pangi in a gold shop (Toko Mas)

Miner in Galangan with a pot of liquid mercury

Sluice box in Galangan

Retort from GTZ project

Appendix 4

Hg concentrations in sediments, tailings and soils

KALIMANTAN AND SULAWESI

KALIMANTAN

Area	Sample	Intervalo	Ref Lab	Hg -200# ppm	Hg 200# ppm	Hg Total ppm	Coor. S	Coord. E	Type
A1	A101		K67	4.12	5.31		01 58 56.32 S	113 17 09.1 E	sediment
A1	A102		K68	1.55	1.55		01 58 56.32 S	113 17 09.1 E	sediment
A1	A103		K72	2.22	0.43		01 58 56.32 S	113 17 11.1 E	sediment
A1	A104		K73	14.00	3.54		01 58 56.32 S	113 17 11.1 E	tailing
A1	A105		K77	2.10	1.63		01 58 34.7 S	113 17 01.8 E	sediment
A1	A106		K79	5.67	2.26		01 58 34.7 S	113 17 01.8 E	tailing
A1	A107		K81	9.78	11.10		01 58 34.7 S	113 17 01.8 E	tailing
A1	A108		K83	1.02	1.32		01 58 34.7 S	113 17 01.8 E	sediment
A1	A109		K86	2.02	4.56		01 58 34.7 S	113 17 01.8 E	sediment
A1	A110		K87	1.39	1.70		01 58 34.7 S	113 17 01.8 E	sediment
A1	A111		K 47	0.6	0.10		01 58 43.7 S	113 17 51.3 E	sediment
A1	A112		K50	1.03	0.80		01 58 43.7 S	113 17 51.3 E	sediment
A1	A113		K66	0.94	0.78		01 58 56.32 S	113 17 09.1 E	sediment
A1	A114		K74	0.53	0.47		01 58 56.32 S	113 17 11.1 E	sediment
A1	A115		K84	0.77	0.29		01 58 34.7 S	113 17 01.8 E	sediment
A1	A116		K88	0.89	1.76		01 58 34.7 S	113 17 01.8 E	sediment
A1	A117		K20	2.17	1.86		01 58 56 S	113 17 08.2 E	sediment
A1	A118		K27	1.09	0.83		01 58 56 S	113 17 08.2 E	sediment
A1	A119		K28	1.23	0.80		01 58 56 S	113 17 08.2 E	sediment
A1	A120		K32	2.80	2.75		01 58 56 S	113 17 08.2 E	sediment
A1	A121		K52	9.34	2.41		01 58 56 S	113 17 08.2 E	tailing
A1	A122		K18	1.23	1.24		01 58 56 S	113 17 08.2 E	sediment
A1	A123		K19	0.77	0.77		01 58 56 S	113 17 08.2 E	sediment
A1	A124		K21	1.00	0.41		01 58 56 S	113 17 08.2 E	sediment
A1	A125		K23	0.08	0.19		01 58 56 S	113 17 08.2 E	sediment
A1	A126		K29	0.79	0.95		01 58 56 S	113 17 08.2 E	sediment
A1	A127		K30	0.68	0.31		01 58 56 S	113 17 08.2 E	sediment
A1	A128		K57	0.11	30.00		01 58 56 S	113 17 08.2 E	sediment
A1	A129		K51	39.70	19.30		01 58 56 S	113 17 08.2 E	tailing
A1	A130		K56	15.20	5.04		01 58 56 S	113 17 08.2 E	tailing
A1	A131		K1	0.60	0.64		01 59 16.4 S	113 17 09.1 E	sediment
A1	A132		K2	0.31	0.24		01 59 16.4 S	113 17 09.1 E	sediment
A1	A133		K3	0.51	0.70		01 59 16.4 S	113 17 09.1 E	sediment
A1	A134		K4	0.94	1.12		01 59 16.4 S	113 17 09.1 E	sediment
A1	A135		K6	0.78	0.78		01 59 16.4 S	113 17 09.1 E	sediment
A1	A136		K9	1.05	1.72		01 59 16.4 S	113 17 09.1 E	sediment
A1	A137		K13	0.68	0.34		01 59 16.4 S	113 17 09.1 E	sediment
A1	A138		K15	0.48	0.73		01 59 16.4 S	113 17 09.1 E	sediment
A1	A139		K16	0.75	0.22		01 59 16.4 S	113 17 09.1 E	sediment
A1	A140		K17	0.44	0.18		01 59 16.4 S	113 17 09.1 E	sediment
A1	A141		K8	1.27	1.80		01 59 16.4 S	113 17 09.1 E	sediment
A1	A142		K11	1.15	1.17		01 59 16.4 S	113 17 09.1 E	sediment
A1	A143		K12	1.24	1.58		01 59 16.4 S	113 17 09.1 E	sediment
A1	A144		K65	0.90	0.63		01 58 56.32 S	113 17 09.1 E	sediment
A1	A145		K61	1.90	0.51		01 58 56 S	113 17 08.2 E	sediment
A1	A146		K62	0.18	26.00		01 58 56 S	113 17 08.2 E	sediment
A1	A147		K7	1.04	0.33		01 59 16.4 S	113 17 09.1 E	soil
A1	A148		K10	2.71	1.01		01 59 16.4 S	113 17 09.1E	soil
A1	A149		K24	0.58	1.24		01 58 56.0 S	113 17 08.2 E	soil
A1	A150		K26	0.41	0.25		01 58 56.0 S	113 17 08.2 E	soil

Area	Sample	Intervalo	Ref Lab	Hg -200# ppm	Hg 200# ppm	Hg Total ppm	Coor. S	Coord. E	Type
A1	A151		K31	1.03	0.48		01 58 56.0 S	113 17 08.2 E	soil
A1	A152		K33	0.78	0.61		01 58 56.0 S	113 17 08.2 E	soil
A1	A153		K35	2.35	1.08		01 58 56.0 S	113 17 08.2 E	soil
A1	A154		K36	2.23	0.58		01 58 56.0 S	113 17 08.2 E	soil
A1	A155		K46	0.77	0.45		01 58 56.0 S	113 17 08.2 E	soil
A1	A156		K47	0.62	0.10		01 58 56.0 S	113 17 08.2 E	soil
A1	A157		K48	1.29	0.72		01 58 56.0 S	113 17 08.2 E	soil
A1	A158		K49	1.59	0.54		01 58 56.0 S	113 17 08.2 E	soil
A1	A159		K50	1.03	0.28		01 58 56.0 S	113 17 08.2 E	soil
A1	A160		K94	2.01	2.15		01 58 56.0 S	113 17 08.2 E	soil
A1	A161		K120	1.37	1.22		01 58 56.0 S	113 17 08.2 E	soil
A1	A162		K121	1.14	1.06		01 58 56.0 S	113 17 08.2 E	soil
A1	A163		K82	2.96	4.86		01 55 36.2 S	113 23 02.3 E	sediment
A1	A164		K25	0.59	0.14		01 58 43.7 S	113 17 51.3 E	tailing
A1	A165		K37	1.28	0.46		01 58 56.0	113 17 08.2 E	tailing
A1	A166		K38	0.24	0.09		01 58 24.0 S	113 17 01.9 E	tailing
A1	A167		K39	0.55	0.45		01 58 24.0 S	113 17 01.9 E	tailing
A1	A168		K40	0.80	0.59		01 58 24.0 S	113 17 01.9 E	tailing
A1	A169		K41	1.39	0.82		01 58 24.0 S	113 17 01.9 E	tailing
A1	A170		K42	0.42	0.14		01 58 24.0 S	113 17 01.9 E	tailing
A1	A171		K43	0.90	0.43		01 58 24.0 S	113 17 01.9 E	tailing
A1	A172		K44	0.42	0.19		01 58 24.0 S	113 17 01.9 E	tailing
A2	A201	0 - 3 cm	KI1	0.05	0.09		01 55 31.2 S	113 22 02 E	sediment
A2	A201	3 - 6 cm	KI3	0.28	0.22		01 55 31.2 S	113 22 02 E	sediment
A2	A201	6 - 14 cm	KI4	0.08	0.08		01 55 31.2 S	113 22 02 E	sediment
A2	A201	14 - 16 cm	KI5	0.21	0.06		01 55 31.2 S	113 22 02 E	sediment
A2	A201	16 - 23 cm	KI6	0.83	0.23		01 55 31.2 S	113 22 02 E	sediment
A2	A201	23 - 27 cm	KI7	1.04	0.33	0.13	01 55 31.2 S	113 22 02 E	sediment
A2	A201	27 - 30 cm	KI8	0.14	0.45		01 55 31.2 S	113 22 02 E	sediment
A2	A201	30 - 34 cm	KI9	0.09	0.09	0.09	01 55 31.2 S	113 22 02 E	sediment
A2	A201	34 - 37 cm	KI10	0.30	0.10		01 55 31.2 S	113 22 02 E	sediment
A2	A201	37 - 43 cm	KI11	0.57	0.62		01 55 31.2 S	113 22 02 E	sediment
A2	A201	43 - 49 cm	KI12	0.12	0.05		01 55 31.2 S	113 22 02 E	sediment
A2	A201	49 - 58 cm	KI13	0.86	0.20		01 55 31.2 S	113 22 02 E	sediment
A2	A201	58 - 66 cm	KI14	1.21	0.16		01 55 31.2 S	113 22 02 E	sediment
A2	A201	66 - 74 cm	KI15	0.09	0.09	0.09	01 55 31.2 S	113 22 02 E	sediment
A2	A201	74 - 76 cm	KI16	0.09	0.09	0.09	01 55 31.2 S	113 22 02 E	sediment
A2	A201	76 - 81 cm	KI17	0.05	0.07		01 55 31.2 S	113 22 02 E	sediment
A2	A201	81 - 87 cm	KI18	0.03	0.03	0.038	01 55 31.2 S	113 22 02 E	sediment
A2	A201	94 - 96 cm	KI20	0.43	0.20		01 55 31.2 S	113 22 02 E	sediment
A2	A201	96 - 104 cm	KI21	0.88	0.88		01 55 31.2 S	113 22 02 E	sediment
A2	A201	104 - 107 cm	KI22	0.16	0.07		01 55 31.2 S	113 22 02 E	sediment
A2	A201	107 - 111 cm	KI23	0.50	0.19		01 55 31.2 S	113 22 02 E	sediment
A3	A301	0 - 2 cm	K89	3.37	2.48		01 59 32.1 S	113 25 26.2 E	sediment
A3	A301	2 - 4 cm	K90	0.25	0.12		01 59 32.1 S	113 25 26.2 E	sediment
A3	A301	4 - 6 cm	K91	1.24	1.05		01 59 32.1 S	113 25 26.2 E	sediment
A3	A301	6 - 8 cm	K92	1.04	0.87		01 59 32.1 S	113 25 26.2 E	sediment
A3	A301	8 - 10 cm	K93	8.43	8.17		01 59 32.1 S	113 25 26.2 E	sediment
A3	A302		K94	2.01	2.15		01 59 32.1 S	113 25 26.2 E	residue

Area	Sample	Intervalo	Ref Lab	Hg -200# ppm	Hg 200# ppm	Hg Total ppm	Coor. S	Coord. E	Type
A4	A401	0 - 2 cm	K114	0.84	0.46		02 01 42.6 S	113 24 44.1 E	sediment
A4	A401	2 - 4 cm	K115	2.24	1.61		02 00 28.3 S	113 24 23.8 E	sediment
A4	A401	4 - 6 cm	K116	5.53	8.79		02 00 28.3 S	113 24 23.8 E	sediment
A4	A401	6 - 8 cm	K117	0.82	0.60		02 00 28.3 S	113 24 23.8 E	sediment
A4	A401	8 - 10 cm	K118	1.32	1.40		02 00 28.3 S	113 24 23.8 E	sediment
A4	A402	A402	K121	2.19	1.68		02 00 28.3 S	113 24 23.8 E	sediment
A5	A501	0 - 2 cm	K106	1.62	0.88		02 01 42.6 S	113 24 44.1 E	sediment
A5	A501	2 - 4 cm	K107	2.19	1.68		02 01 42.6 S	113 24 44.1 E	sediment
A5	A501	4 - 6 cm	K108	1.16	0.62		02 01 42.6 S	113 24 44.1 E	sediment
A5	A501	6 - 8 cm	K109	21.80	9.26		02 01 42.6 S	113 24 44.1 E	sediment
A5	A501	8 - 10 cm	K110	2.08	2.93		02 01 42.6 S	113 24 44.1 E	sediment
A5	A501	10 - 12 cm	K111	3.03	2.24		02 01 42.6 S	113 24 44.1 E	sediment
A5	A501	12 - 14 cm	K112	2.52	1.79		02 01 42.6 S	113 24 44.1 E	sediment
A6	A601	0 - 3 cm	K96	0.71	0.72		02 02 09.9 S	113 25 42.8 E	sediment
A6	A601	3 - 6 cm	K97	4.63	4.55		02 02 09.9 S	113 25 42.8 E	sediment
A6	A601	6 - 9 cm	K98	0.93	0.65		02 02 09.9 S	113 25 42.8 E	sediment
A6	A601	9 - 12 cm	K99	3.15	2.11		02 02 09.9 S	113 25 42.8 E	sediment
A6	A601	12 - 15 cm	K100	1.35	1.57		02 02 09.9 S	113 25 42.8 E	sediment
A6	A601	15 - 18 cm	K101	0.94	0.82		02 02 09.9 S	113 25 42.8 E	sediment
A6	A601	18 - 21 cm	K102	1.50	1.00		02 02 09.9 S	113 25 42.8 E	sediment
A6	A601	21 - 24 cm	K103	4.51	2.94		02 02 09.9 S	113 25 42.8 E	sediment
A6	A601	24 - 27 cm	K104	3.23	1.90		02 02 09.9 S	113 25 42.8 E	sediment

SULAWESI

Sample	Ref Lab	Hg -200# (ppm)	Hg 200# (ppm)	Total	Coor. S	Coord. E	Type
A101	T5	73.50	39.10		01 30 53.9 S	125 00 48.8 E	sediment
A102	T6	93.30	26.20		01 30 53.9 S	125 00 48.8 E	sediment
A201	C17	89.20	44.2		01 31 50.3 S	124 58 48.0 E	sediment
A202	C23	88.80	48.7		01 31 50.3 S	124 58 48.0 E	sediment
A203	C26	88.80	58.0		01 31 50.3 S	124 58 48.0 E	sediment
A204	C30	38.90	33.20		01 31 50.3 S	124 58 48.0 E	sediment
A205	F1	271.20	308.70		01 31 51.5 S	124 58 52.1 E	sediment
A206	F2	78.90	78.90		01 31 51.5 S	124 58 52.1 E	sediment
A207	F3	195.40	170.50		01 31 51.5 S	124 58 52.1 E	sediment
A208	F5	195.40	170.50		01 31 51.5 S	124 58 52.1 E	sediment
A209	F6	103.40	74.3		01 31 51.5 S	124 58 52.1 E	sediment
A210	F7	130.30	88.7		01 31 51.5 S	124 58 52.1 E	sediment
A211	F10	65.10	74.0		01 31 51.5 S	124 58 52.1 E	sediment
A212	F11	94.70	91.5		01 31 50.3 S	124 58 48.0 E	sediment
A213	T13	182.70	94.5		01 31 50.3 S	124 58 48.0 E	sediment
A214	T15	117.70	75.2		01 31 50.3 S	124 58 48.0 E	sediment
A215	T23	110.60	5.39		01 31 50.3 S	124 58 48.0 E	sediment
A216	Tat1	201.60	149.30		01 31 51.5 S	124 58 52.1 E	sediment
A217	TaT2	486.70	621.10		01 31 51.5 S	124 58 52.1 E	sediment
A218	Tat6	88.50	62.90		01 31 51.5 S	124 58 52.1 E	sediment
A219	Tat7	60.90	43.70		01 31 51.5 S	124 58 52.1 E	sediment
A220	TSF	38.80	16.50		01 31 51.5 S	124 58 52.1 E	sediment
A221	TaT3	23.80		23.80	01 31 51.8 S	124 58 55.6 E	sediment
A222	TaT4	13.30		13.30	01 31 51.8 S	125 58 55.6 E	sediment
A223	TaT5	129.40		129.40	01 31 51.8 S	126 58 55.6 E	sediment
A224	F29A	6.21	4.36		01 31 49.8 S	124 58 55 E	sediment
A225	Gala-10	10.1	5.21		01 31 51.2 S	124 58 53.2 E	sediment
A226	Gala-8	10.30	2.94		01 32 05.8 S	124 55 48.3 E	sediment
A227	TaT9	39.40	39.40		01 31 51.5 S	124 58 52.1 E	sediment
A228	C1	113.3	113.3		01 32 00.9 S	124 59 44.2 E	tailing
A229	C2	190.9	208.8		01 32 00.9 S	124 59 44.2 E	tailing
A230	C9	121.7	95.3		01 32 00.9 S	124 59 44.2 E	tailing
A231	F4	863.9	863.9		01 31 51.2 S	124 58 53.2 E	tailing
A232	F12	835.4	375.5		01 31 51.2 S	124 58 53.2 E	tailing
A233	F13	1269.2	246.4		01 31 51.2 S	124 58 53.2 E	tailing
A234	F14	160.5	26.4		01 31 51.2 S	124 58 53.2 E	tailing
A235	F40	333.3	333.3		01 31 51.2 S	124 58 53.2 E	tailing
A236	F41	593.4	550.6		01 31 51.2 S	124 58 53.2 E	tailing
A237	F42	471.4	292.2		01 31 51.2 S	124 58 53.2 E	tailing
A238	F43	437.9	426.2		01 31 51.2 S	124 58 53.2 E	tailing
A239	F44	399	299.8		01 31 51.2 S	124 58 53.2 E	tailing
A240	F45	317.6	147.6		01 31 51.2 S	124 58 53.2 E	tailing
A241	F46	208.9	142.1		01 31 51.2 S	124 58 53.2 E	tailing
A242	F47	65.3	23.8		01 31 51.8 S	124 58 55.6 E	tailing
A243	F48	134.6	102.2		01 31 51.8 S	124 58 55.6 E	tailing
A244	F49	275.9	354.9		01 31 51.8 S	124 58 55.6 E	tailing
A245	T3	139.5	98.7		01 31 51.2 S	124 58 53.2 E	tailing
A246	T4	916.30	916.30		01 31 51.2 S	124 58 53.2 E	tailing
A247	F16	12215.30	690.80		01 31 51.2 S	124 58 53.2 E	dust

Sample	Ref Lab	Hg -200# (ppm)	Hg 200# (ppm)	Total	Coor. S	Coord. E	Type
A248	F19	229.30	196.60		01 31 51.2 S	124 58 53.2 E	dust
A249	C8	17.6	9.8		01 31 55.9 S	124 59 01.9 E	soil
A250	C11	113.3	110.3		01 31 58.7 S	124 59 39.3 E	soil
A251	F15	698.6	876.9		01 31 58.7 S	124 59 39.3 E	soil
A252	F19b	229.3	196.6		01 31 58.7 S	124 59 39.3 E	soil
A253	F25	31.9	21.9		01 31 51.2 S	124 58 53.2 E	soil
A254	F26	10.5	8.2		01 31 49.8 S	124 58 55.0 E	soil
A255	F27	35.1	29.8		01 31 49.8 S	124 58 55.0 E	soil
A256	F28	10.3	8.3		01 31 49.8 S	124 58 55.0 E	soil
A257	F29	8.4	9.7		01 31 49.8 S	124 58 55.0 E	soil
A258	F30	14.1	12.0		01 31 52.5 S	124 58 58.4 E	soil
A259	F31	4.9	4.5		01 31 52.5 S	124 58 58.4 E	soil
A260	F33	2.6	2.1		01 31 52.5 S	124 58 58.4 E	soil
A261	F34	6.9	4.0		01 31 52.5 S	124 58 58.4 E	soil
A262	F35	8.1	5.5		01 31 52.5 S	124 58 58.4 E	soil
A263	F36	10.2	7.7		01 31 55.9 S	124 59 01.9 E	soil
A264	F37	10.7	9.1		01 31 55.9 S	124 59 01.9 E	soil
A265	F39	11.5	9.4		01 31 55.9 S	124 59 01.9 E	soil
A266	T16			2.00	01 31 18.7 S	125 00 30.1 E	water
A267	C12			2.10	01 32 00.9 S	124 59 44.2 E	plants
A268	C12			4.16	01 32 00.9 S	124 59 44.2 E	plants
A269	C13			5.76	01 32 00.9 S	124 59 44.2 E	plants
A270	C15			6.71	01 32 00.9 S	124 59 44.2 E	plants
A271	C16			1.03	01 32 00.9 S	124 59 44.2 E	plants
A272	C18			12.20	01 32 00.9 S	124 59 44.2 E	plants
A273	C19			21.60	01 32 00.9 S	124 59 44.2 E	plants
A274	C19			388.30	01 32 00.9 S	124 59 44.2 E	plants
A275	C21			4.93	01 32 00.9 S	124 59 44.2 E	plants
A276	T18			0.31	01 32 00.9 S	124 59 44.2 E	plants
A277	T20			0.20	01 32 00.9 S	124 59 44.2 E	plants
A278	T21	74.80	86.40	86.40	01 32 00.9 S	124 59 44.2 E	plants
A279	T22			34.20	01 32 00.9 S	124 59 44.2 E	plants
A280	T51			0.38	01 32 00.9 S	124 59 44.2 E	plants
A281	T52			0.26	01 32 00.9 S	124 59 44.2 E	plants
A301	T1	154.30			01 31 50.5 S	124 57 36.6 E	sediment
A302	T2	256.70	89.70		01 31 50.5 S	124 57 36.6 E	sediment
A303	T9	206.90	171.90		01 31 54.4	124 57 24.4	sediment
A304	T12			0.31	01 31 54.4 S	124 57 24.4 E	plants
A305	T12a			0.13	01 31 54.4 S	124 57 24.4 E	plants
A306	C7			7.50	01 32 05.8 S	124 55 48.4 E	plants
A307	C5			37.80	01 32 05.8 S	124 55 48.4 E	plants
A308	T10			8.57	01 31 54.4 S	124 57 24.4 E	animal
A309	T11			2.13	01 31 54.4 S	124 57 24.4 E	animal
A310	T19			2.24	01 31 54.4 S	124 57 24.4 E	animal
A311	T30			0.08	01 31 54.4 S	124 57 24.4 E	animal
A401	T7	60.60	41.40		01 33 29.2 S	124 56 14.9 E	sediment
A402	T8	114.80	93.80		01 33 10.8 S	124 56 19.8 E	sediment
A501	T41	5.85	3.96		01 36 05.4 S	124 52 50.2 E	sediment
A502	T44	2.86	1.89		01 36 05.4 S	124 52 50.2 E	sediment
A503	T45	2.63	3.97		01 36 05.4 S	124 52 50.2 E	sediment

Sample	Ref Lab	Hg -200# (ppm)	Hg 200# (ppm)	Total	Coor. S	Coord. E	Type
A504	T47	3.55	5.67		01 36 05.4 S	124 52 50.2 E	sediment
A505	T48	6.53	3.82		01 36 05.4 S	124 52 50.2 E	sediment
A506	T38	3.8	2.1		01 36 05.4 S	124 52 50.2 E	soil
A507	T40	10.9	5.6		01 36 05.4 S	124 52 50.2 E	soil
A601	T34	8.36	4.44		01 36 51.0 S	124 52 19.5 E	sediment
A602	T42	14.80	7.0		01 36 51.0 S	124 52 19.5 E	sediment
A603	T43	9.61	5.34		01 36 51.0 S	124 52 19.5 E	sediment
A604	F8	32.9	31.1		01 36 51.0 S	124 52 19.5 E	soil
A605	F9	10.0		10.0	01 36 51.0 S	124 52 19.5 E	soil
A606	T32	8.4	5.4		01 36 51.0 S	124 52 19.5 E	soil
A607	T32A	12.9	8.2		01 36 51.0 S	124 52 19.5 E	soil
A608	T36			0.05	01 36 22.1 S	124 52 34.6 E	water
A609	T50			0.10	01 36 22.1 S	124 52 34.6 E	water
A610	Coral			0.01	01 36 51.0 S	124 52 19.5 E	animal
A701	B1	18.50	11.00		01 30 27.3 S	124 58 50.7 E	sediment
A702	B2	34.70	24.50		01 30 27.3 S	124 58 50.7 E	sediment