THE EFFECT OF MERCURY EMISSIONS FROM DIWALWAL SMALL SCALE GOLD MINING OPERATIONS TO ENVIRONMENT AND HEALTH

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1.0 Introduction

Mercury has been used in the recovery of free gold by *artisanal and small-scale* gold mining activities for the most part of the last century. The worldwide demand for gold and the applicability of an effective, simple and cheap mercury-based amalgamation process to alluvial as well as vein type gold deposits have driven a significant sector of largely itinerant, poorly educated populace with little other employment alternatives to practiced *artisanal and small-scale* mining activities.

In the Philippines, *artisanal and small-scale* mercury-based gold mining has been reportedly practiced mostly in Luzon before the discovery of high-grade gold deposits in Mindanao in the early 1980's. As in other parts of the world, *artisanal and small-scale* mining continues to hold out the promise to a bright prospect and a real means of livelihood to about 100,000 deprived Filipinos. At the same time, this promise tends to reinforce the vicious circle of appalling working conditions, poverty in communities, social dislocations and significant environmental damage as a consequence of operating outside any legal and regulatory framework, including the unregulated use of mercury. This is more evident in the Province of Davao in general and Mt. Diwalwal,in particular where about 15,000 people are engaged in *small-scale* mining, mineral processing and other related activities up to present.

Amalgamation continues to be the preferred method of extracting free gold by the *artisanal and small-scale* miners due to the ease and efficiency of operation. The lack of alternative technologies coupled with the need to earn a living by extracting gold within the fastest time possible has resulted in the uncontrolled release of mercury to the environment. The practice of blow-torching the amalgam in open vessels has caused air pollution due to the release of mercury as vapor. Direct amalgamation of ground ore without prior gravity concentration and the use of excessive quantities of mercury have entailed contamination of water ways due to discharge of tailings laden with inorganic mercury (metallic mercury). There is growing concern that this pollution affects also international waters.

In their efforts to assist the Philippines in abating mercury pollution emanating from small-scale gold mining, the United Nations Industrial Development Organization (UNIDO) have implemented the project "Assistance in Reducing Mercury Emissions in Highly Contaminated Gold Mining Areas in Mindanao – Phase I". Among the major goals of the project were the determination of the extent of pollution along Naboc river (the main river system draining the Diwalwal operations) and their neighboring areas including rice fields and banana plantations; and the assessment of mercury levels in persons directly and non-directly exposed to mercury in small-scale mining areas and treatment of diagnosed Hg intoxicated individuals

2.0 Scope of Work/Contracts

The assessment studies were contracted to three international experts, namely **Dr. J.D. Appleton** of the British Geological Survey, **Dr. Jason Weeks** of J.M. Weeks of Centre for Ecology and Hydrology, Cambridgeshire United Kingdom and **Dr. Stephan Boese O'Reilly** of the Institute of Forensic Medicine, Univerity of Munich.

Dr. Appleton was responsible for the study on the extent of mercury and other related chemical pollution and neighboring areas (Appleton, 2000). Dr. Weeks conducted the study of the potential risks to human health from consumption of rice cultivated in paddy fields irrigated by mercury-contaminated mine waste water. It also included sampling of bananas, bivalves and fishes grown in the locality (Weeks, 2000). Dr. O'Reilly, together with another German doctor, Stefan Maydl evaluated the effect of mercury as a health hazard due to gold mining and mineral processing activities (O'Reilly et.al., 2000). The conduct and results of these individuals studies are embodied in this document.

3.0 Methodology

3.1 Field Sampling and Analysis

3.1.1 Water and sediment samples

Drainage samples were collected at appropriate intervals along the Naboc River, from sub-catchments directly influenced by contemporary mining and also from control sites in tributaries and rivers not influenced by current mining activities. The Agusan River was sampled both above and below the point where contamination from the Naboc enters this major river.

Stream and well water pH, temperature, Eh and conductivity were determined in the field using a series of temperature-compensated electrodes and meters (Plates 5, 7 and 8). Water samples for chemical analysis were filtered through 50 mm diameter *Sartorius Sartolab* P 0.45 µm disposable SFCA membranes using 50 ml disposable syringes and collected into 250 ml LPDE bottles (*Nalgene*^{TM}). Some water samples for analysis at the BGS were collected using 25 mm diameter, 0.45 µm Millipore$^{\text{TM}}$ cellulose acetate membranes into 30 ml HPDE bottles (*Nalgene*^{TM}). Coarse prefilters were used in conjunction with the 0.45 mm cellulose disks on all obviously turbid samples.

At each site, the suite of water samples collected included:-

(a) 250 ml filtered water preserved with 1% v/v HNO_3 (*Merck*) for determination of Hg by Hg analyser and Cu, Cd, Cr, Pb, Zn, Cd by AAS.
(b) 250 ml unfiltered with pH adjusted to 12 with solid NaOH for CN analysis by SIE.
(c) 500 ml filtered, unacidified water for Na, K, Ca, Mg, SO_4^{2-}, and Cl^- analysis.

A number of 30 ml samples, filtered and preserved with 0.3 ml conc. HNO_3 + 0.3 ml 0.2 vol.% K_2CrO_7 were collected for total Hg analysis by cold vapour atomic fluorescence spectroscopy (CVAFS) to a practical detection limit of 30 ng/l. These analyses were carried out at the BGS laboratories in the UK.

Bottom sediment (BS) samples, each of 100-200 grams, were collected by wet-screening of river or stream-bed sediment through a <150 µm sieve, using a minimal amount of water to avoid the loss of fine silt and clay fractions (Plates 8 and 9). Samples were sealed in plastic securitainers to avoid evaporative losses and oxidation.

Suspended particulate matter (SPM) samples were obtained by filtering 500 ml water through 47 mm diameter, 0.45 µm Cellulose Nitrate Membrane Filters (*Whatman*) using 250 ml and 500 ml capacity *Nalgene* Filter Holders and Receivers and a hand operated vacuum pump (Plate 6). Where the sediment load was high, a number of filters had to be used. The filter membranes were carefully removed to avoid contamination and stored in 30 ml *Sterilin* tubes. The filtered water was used for determination of Na, K, Ca, Mg, SO_4^{2-}, and Cl^- analysis.

3.1.2 Rice grains, bananas, bivalves and fish samples

In many areas of the irrigation canal network Appleton (2000) reports between that between 5 to 15 cm of silt is deposited in the rice paddies. It is reported that up to 50 cm silt can be deposited, although this may be a cumulative figure. Each paddy field is flooded 4 times each year and the siltation has been observed since 1991 approximately 2 to 5 cm of silt is ploughed into the top 10-20 cm of the soil profile every year (Appleton, 2000) so any Hg contamination associated with this silt will be thoroughly mixed into the rice root zone. The amount of silt is greatest in the east (close to the source of the irrigation water) and declines progressively to the west. Irrigation canals have to be desilted approximately every 2 to 3 months. It is reported that about 50 cm of silt is removed from the main canal every 3 months (Appleton, 2000).

Random samples of rice (*Oryza sativa* L.) grain were taken from the lower and upper Naboc communal irrigation system (see Figure 1). Rice grain was collected by hand either from the mature ripe rice plants *in situ*, or where rice had previously been harvested it was taken from drying beds (open concrete areas cast to facilitate sun drying (see plate 2)). In the latter case each sample comprised of a composite of at least 6 sub-samples of these areas. Approximately 300g were taken for each location in a randomized fashion. Samples were placed in plastic bags and kept in a fridge (5°C) before being dried and subsequently analyzed. Grains were thoroughly washed (once only) dried at a low temperature <40°C in an oven until a constant weight was achieved. The rice was then milled to a fine powder. The hull of the rice was removed prior to milling. It is difficult to relate the collected rice grain to a specific locality or paddy field but the grain is representative of a truly homogeneous pool collected from the rice growing irrigated area under the influence of the mining activities. Samples were decomposed using nitric acid and analyzed for total inorganic mercury contents using AAS

Additionally, for the mercury analyses rice was also cooked (following one washing) in the traditional way to assess the variation in rice Hg levels following normal cooking procedures.

Appleton (2000) reported that commercial banana plantations between the Naboc and Mamunga Rivers were spray irrigated with water extracted from the lower section of the Naboc, at a point close to the Agusan confluence. He observed a thin white film of clay-silt on the leaves and trunks of the banana plants other banana plantations were spray irrigated with water pumped from the Agusan River. Thus it was decided to investigate the levels of Hg, Cd and Pb in banana crops.

Bananas (near ripe) were cut from trees growing under protective plastic bags from three areas each under different irrigation regimes. Bananas were taken from plantations in Mamonga (irrigated by the Naboc), the Makopa (irrigated by the Agusan) and in Babag (irrigated by the Anaan). Collected bananas were stored at 5°C in a fridge until airmailed back to the Mines and Geosciences Bureau for subsequent Hg, Cd and Pb analysis. The plant tissue was digested wet in hot nitric acid.

Freshwater bivalves (mussels) were analysed for total inorganic Hg, Pb and Cd concentrations in their soft tissues. Mussels are considered ideal as biomonitors of heavy metal contamination on account of their limited mobility, widespread distribution and tendency for biomagnification of ambient heavy metal concentrations. These freshwater mussels also formed part of the human diet in the region. Samples of mussels were collected from two different locations, one a pond fed by the Naboc and the other, the Naboc River proper. All specimens were returned alive to the makeshift laboratory in Monkayo where they were rinsed in clean bottled water. The edible (by humans) soft tissues of the mussels taken from the two locations were carefully dissected (removing the gut contents) from their shells (allowing the opened shell to drain onto tissue paper) and frozen in self-sealing individual plastic bags at minus 18-20°C (±2°C)(Williams et al., 1999). These samples were subsequently dried (<50°C), weighed and acid digested prior to analysis of total Hg, Cd and Pb contents.

Fish (*Tilapia* spp.) (mostly juvenile) were collected by hook and line fishing from two locations, the Agusan tributary and the Naboc River. Species were identified only by local name. Muscle tissue was removed (fillet) using stainless steel dissecting tools, from the freshly killed fish and samples frozen individually in Sterilin tubes (-18-20°C (±2°C)) as before until analyses for total Hg, Cd, and Pb contents could be undertaken by the Mines and Geosciences Bureau, Diliman.

In order to ensure the value of the analyses, the Mines and Geosciences Bureau implemented a rigorous quality control programme. These included the use of certified international reference materials, which included National Research Centre for Certified Reference Materials (NRCCRM) rice (GBW08508) (0.038 µg/g certified value), and National Research Council, TORT-1 (lobster hepatopancreas). The precision and bias of the chemical analysis was less than 10% with the exception of some Pb results which were subsequently reanalysed with greater precision.

3.2 Human Bio-monitoring and Medical Examination

To evaluate the influence of this mercury burden on the local population and the extent of the possible health effects, 323 participants were examined. These participants consisted of: workers from Diwalwal, local families from Monkayo (Naboc, Tubo-Tubo, Babag and Mamunga) including children and a control group in Davao. The workers were mainly mercury exposed ball-millers and amalgam smelters. Miners were intentionally excluded. It could be expected that their mercury burden was a similar order of magnitude than of other (non occupationally mercury exposed) inhabitants of Mount Diwata. But many of the health problems of the miners may derive from their hard underground work. Therefore it would be almost impossible to distinguish in this group between negative health effects caused by mercury and by mining. A written consent of every participant was achieved before performing any examination.

3.2.1 Questionnaire:

The participants filled in a questionnaire with assistance from midwifes or nurses. Questions included:

- Working in a gold plant or mineral processing plant?
- 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?

3.2.2 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 and ataxia (walking or standing)
- Tremor: tongue, eye-lids, finger to nose, pouring, posture holding and the Romberg test
- Test of alternating movements or test for dysdiadochokinesis
- Test for irregular eye movements or so called nystagmus
- Test of the field of vision
- Reflexes: knee jerk reflex and biceps reflex
- Pathological reflexes: Babinski reflex and sucking reflex
- Salivation and dysathria
- Sensory examination

3.2.3 Neuro-psychological testing:

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

3.2.4 Specimens

The following specimens were taken, and two tests (malaria and proteinuria) were performed immediately:

a. Blood (EDTA-blood 10 ml)
    Malaria smear: None of the participants had a positive malaria smear.
b. Urine (spontaneous urine sample 10 ml)
    Urine protein test
c. Hair

From 323 participants on the Philippines 323 blood samples, 313 urine samples and 316 hair samples were taken by Dr. Böse-O'Reilly. The blood samples were taken in EDTA-coated vials. The urine samples were acidified with acetic acid. To avoid degradation, all samples were stored permanently and transported by flight to Germany in an electric cooling box. Until analysis the samples were stored continuously at 4 °C.

3.2.5 Sample Preparation

Hair: In all cases the scalp near part from 0 – 3 cm of the hair was selected. 150 – 250 mg of these hair segments were treated with 1.0 ml nitric acid (min 65%, suprapur grade, E. Merck, Darmstadt, Germany) in polypropylene test tubes, locked with screw caps for approximately 12 hours at 50 °C in a heating block. After cooling, the clear solutions were filled up to 5.0 ml with redistilled water and vortexed. Aliquots of these solutions were analyzed. Intentionally washing steps with water, detergents or organic solvents like acetone were not performed before the solution. 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 the hair samples from the Philippines supported this assumption. After washing some samples from the same strain totally unreproducible results were obtained. Therefore the hair samples were dissolved without any further pretreatment.

Blood, urine: Aliquots of up to 1.0 ml were measured directly without further pretreatment. This was possible, because sodium-borohydride was applied for the mercury reduction and all nascent mercury vapour was inter-collected on a gold-platinum-net (method see below).

4.0 Results and Discussion

4.1 Environmental Monitoring

4.1.1 Water quality

Hg in filtered water samples from the Naboc River exceeds all drinking water quality criteria as well as (i) the U.S. EPA National recommended water quality criteria for the protection of aquatic organisms and their uses and (ii) the UK-DOE “I” (imperative) value recommended for compliance with EC Shellfish Waters Directive (79/923/EEC).. Whereas high Hg loads in solution have been reported previously and these clearly constituted a significant health hazard at that time, the general decline in the use of amalgamation for gold extraction suggests that the risk from Hg in solution has declined.

Cyanide exceeds drinking water quality criteria at the Depot site (500 ppb), but decreased to about 35 ppb in the lower reaches of the Naboc River, which is well below drinking water quality threshold but slightly above the CMC value of the U.S. EPA Freshwater Criteria for the Protection of Aquatic Life.

Quality criteria for Hg and CN are not exceeded in water samples from the Agusan River or in drinking water wells in the Tubo Tubo, Naboc, Mamonga and Babag areas.

Total suspended solids (TSS) in the Naboc River exceeds DENR Class D water quality criteria by a factor of 2 to 73 but is only marginally above the threshold in the Agusan River. Water from the Naboc River is not used for drinking because of its high suspended sediment load (and presumably also high bacterial and viral loads). The high TSS will effectively prevent the survival of most aquatic macrobiota.

If the temporal variations related to changes in contaminant fluxes and hydraulic regime that have been recorded during the present survey are a common occurrence, then higher Hg and CN concentrations are likely to occur periodically and may pose a hazard to aquatic biota.

4.1.2 Sediment quality

Hg concentrations in bottom and suspended sediment in the Naboc and Agusan Rivers (sampling point was five kilometers downstream from Agusan/Naboc River confluence) exceed the Toxic Effects Threshold for the Protection of Aquatic Life by factors of up to 55 and 166, respectively.

There is no evidence for the occurrence of major 'hot-spots' of mercury contamination in the bottom sediments. Discrete 'hot-spots' may exist (such as where there are accumulations of organic material on the riverbed) but it would require a very expensive and detailed survey to verify whether such 'hot-spots' do exist. The balance of the available evidence indicates a relatively homogeneous level of Hg contamination in the bottom sediment.

Release of Hg into river water as a result of methylation of Hg in bottom sediment may occur but there is no evidence available indicating that this results in Hg concentrations that exceed water quality criteria nor how serious an impact Hg in bottom sediment has on the quality of fish and other aquatic biota. There is also the risk that these Hg contaminated sediments will be transferred downstream during periods of high hydraulic flow.

4.1.3 Soil quality

Rice paddy fields in the Lower and Upper Naboc Communal Irrigation Systems have been irrigated over the last decade using Hg-contaminated water from the Naboc River. Multiple influxes of irrigation water has deposited silt containing up to 90 mg/kg Hg which has been ploughed into the upper 20-25 cm of the soil profile. Hg in soil samples taken from rice paddy fields ranges from 0.05 to 96 mg/kg (average 24 mg/kg; median 12 mg/kg). Whereas there appear to be no DENR guideline values for Hg in agricultural soils, the maximum permissible concentration of Hg in UK agricultural soils (1mg/kg) is clearly exceeded in many of the soil samples. Limit values for Cd, Cu, Pb and Zn in agricultural soils adopted by the UK are not exceeded in any of the Naboc soil samples.

Much lower Hg concentrations within the range expected for uncontaminated soils characterise the soils on which corn and bananas are cultivated. This is because the soils on which these crops are cultivated are not irrigated with Hg-contaminated water from the Naboc Irrigation Communal System.

4.1.4 Food crops

Levels of total mercury in the rice crop correlated poorly with measured soil mercury concentrations suggesting that mercury was not accumulated within the developing rice grains. Cooking rice grains by boiling showed a tendency to reduce further the concentrations of total mercury within the rice. Risks posed to humans from consuming the heavy metals Hg, Pb and Cd in the rice have been calculated.

It appears that the measured Hg concentrations in the rice reflect natural ambient background concentrations likely to be found in this crop under such conditions.

The average daily intake of Cd from the rice is 87.2 µg Cd/d (300g X 0.2907 µg Cd/g). This figure (for one weeks' intake 7 X 87.2 = 610 µg) exceeds the provisional tolerable weekly intake (PTWI) of 400 - 500 µg Cd recommended by the FAO and WHO. However, if we adjust this value for body weight (50 kg) then 1.744 µg/d/kg is taken in with the rice. An assumption of 7.5% uptake ratio in the alimentary tract for both Cd and Pb (Zhang et al., 1999) will give an estimated uptake of 6.54 µg Cd/d. This value is less than the 10 – 40 µg/d WHO limit.

The average daily intake of Pb from rice in this study is 14.3 µg Pb/d (300g X 0.0.0479 µg Pb/g). This figure is only 3.34% of the provisional maximum daily intake of 430 µg Pb recommended by the FAO and WHO. However, if we adjust this value for body weight (50 kg) then 0.2874 µg/d/kg is taken from the rice. An assumption of 7.5% uptake ratio in the alimentary tract for Pb (Zhang et al., 1999) will give an estimated uptake of 1.066 µg Pb/d. This final value is considerably below the recommended daily intake.

Although human health studies have been undertaken, regular consumption of the rice by the residents in the study area poses some hazard as a potential health problem from long-term metal exposure especially for Cd and Pb but to a lesser extent for Hg. The residents living near the study area regularly consume the rice grown on soils contaminated by the mine. The average metal intake from the rice by these residents was estimated to be 4.5 µg Hg /day; 87.2 µg Cd/d; 14.4 µg/Pb/d, respectively. Only for Cd do these values exceed the tolerable daily intakes recommended by FAO and WHO. Thus it is possible that long-term regular consumption of locally grown/collected vegetables and rice poses some potential health problems in view of the limited data presented from this study. Jung & Thornton (1997) were also able to demonstrate similar elevations in Cd and Pb in rice grown in paddy fields around a Pb-Zn mine in Korea. Zhang et al. (1998b) using a duplicate rice diet in a study in Manila demonstrated that only 18% of dietary Pb and for cereals (i.e. all rice, wheat and maize in combination) only 24% of total Pb ingestion could be attributed to diet. The calculation from the published data on air quality in Manila suggested that another and yet a greater source of Pb was atmospheric air, which may account for 85% of total Pb uptake. It is likely that there is limited transfer of accumulated heavy metals to the maturing rice grain. Work by Lee et al. (2000) has demonstrated measured elevated concentrations of As, Cd, Cu, Pb and Zn in rice plant stalks but these were not correlated with concentrations of the same heavy metals measured in the rice grain.

Measured concentrations of heavy metals (Hg, Cd and Pb) in the other groups of food types collected such as bananas were typically low and within appropriate food safety standards for such items.

There is some concern that if fish or shellfish from either river are used as part of a staple regular diet then there may be implications for exceeding WHO guidelines on weekly intake levels of mercury (or methylmercury) with possible negative consequences on human health.

4.2 Medical Examination and Hg Bio-monitoring Results

From the total group of 323, 16 cases had to be excluded from further statistical analysis due to missing data (only blood samples could be taken in these cases without any further medical or neurological investigation)and possible bias(i.e., participants showed severe neurological diseases, like stroke or Parkinson’s disease). The remaining group of 307 participants was subdivided to the following sub-groups due to residence and occupation criteria. The following subgroups were formed:

1. Control: 42 participants from Davao, without special Hg burden.
2. Downstream: 100 participants living in the barangays of Mamunga, Babag, Tubo-Tubo and Naboc in the Monkayo area at the base of Mt. Diwata. They may be secondary Hg-burdened, especially by Hg-contaminated water flowing down from Mt. Diwata. Excluded from this group are a few persons from this area, which may be occupationally Hg burdened. Those are grouped in 4 and 7.
3. Diwata, no Hg occupation: 43 participants, living in Diwalwal without any special occupational Hg-burden.
4. Diwata, possibly Hg exposed by family: 20 family members possibly exposed by Hg, brought home with Hg contaminated clothes etc.
5. Diwata, ball-millworkers: 55 workers in ball mills
6. Diwata, amalgam smelter: 41 workers, smelting gold-amalgam

7. Diwata, other Hg occupation: 6 participants, which have declared that they have occupationally contact to Hg, but do not belong to group 5 or 6.

4.2.1 Clinical Test Results

The clinical impression was, that a fair amount of workers from Diwalwal showed severe symptoms that could very well be related to the classical picture of a mercury intoxication. They reported about fatigue, tremor, memory problems, restlessness, loss of weight, metallic taste and sleeping disturbances. The experts found intentional tremor, mainly fine tremor of eye lids, lips and fingers, ataxia, hyperreflexia and sensory disturbances as well as a bluish discoloration of the gums. In contrast to this, the participants from the low land area of Monkayo and surrounding barangays showed less clinical signs. They complained more about other symptoms, which could be related to mercury, such as: headache, vision problems and nausea. Moreover, the control group in Davao - staff from the local Mines and Geoscience Office - were healthy and did not show signs of any special health problems.

4.2.2 Bio-monitoring Test Results (Blood, Urine and Hair Hg Burdens)

As expected, the highest burden is found in the Hg-occupational burdened groups of ball-mill workers and amalgam smelters, followed by other inhabitants of the Mt. Diwata area. A major part of the tested participants has an elevated internal mercury burden, which exceeds in many cases toxicological threshold limits (see Table 1). 55% and 61% of the ball-mill workers and amalgam smelters, respectively, have mercury levels above toxicological threshold limits (HBM II). Approximately 20% of both groups exceed even the high occupational threshold limit, as valid in Germany (BAT-value).

	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)	

Table 1. Toxicologically established threshold limits for mercury in blood, urine and hair (HBM = Human Bio-Monitoring; BAT = Biologischer Arbeitsstoff-Toleranzwert; BEI = Biological Exposure Indices)

The mercury concentrations in blood and urine of people living downstream in the Monkayo area at the base of Mt. Diwata (group downstream) were lower than in the control region of Davao, whilst mercury in hair was equal. Participants from Monkayo, which are only exposed by an environmental pathway, but not occupationally, do exceed in 26% the HBM II-threshold limit. The mercury concentration in the blood and hair samples from the control group from Davao was unexpectedly high (19.05% > HBM II), not only in comparison to the population of Mt. Diwata and the Monkayo area downstream, but also in an international comparison. In contrast to this, the mercury concentration in urine in Davao was in an acceptable range. This distribution (high Hg in blood and hair, moderate in urine) is characteristic for a methyl-mercury burden, e.g. from high mercury burdened marine food.

4.2.3 Basis for diagnosing “CHRONIC MERCURY INTOXICATION”

From the combined results of the bio-monitoring and clinical tests, each participant was evaluated on the level of chronic mercury intoxication. An “intoxication” is defined by the presence of the toxin in the body and typical adverse health effects. Deriving from this interpretation, a balanced result is determined by the combination of mercury concentration in blood, urine and hair and the negative health effects, as summarized in the medical score sum (from clinical test results). 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.

The table below summarizes the combination of mercury levels and results of clinical tests in deciding for the diagnosis “chronic mercury intoxication”. An individual with combined result with the plus (+) sign is recommended for detoxification.

		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	+	+	+

Table 2: Basis for Diagnosing Chronic Mercury Intoxication

4.2.4 Findings: Participants Recommended for Detoxification

Based on the above table, chronic mercury intoxication, was identified in high percentage of the population in the Mt. Diwata area, e.g. ball-mill workers in approximately 65% (36 out of 55) and amalgam smelters in 85% (35 out of 41)(see Table 3 below). These are the participants who are in direct contact to either mercury fumes or inorganic mercury. To a lesser extent, 38% (38 out of 100) mercury intoxication was found in the downstream population in the plain of Monkayo. No mercury intoxication was found in the control area of Davao, despite the fact that about 19 % of them have bio-monitors higher than HBM II.

These percentages, however cannot be projected directly to the total population (or sub-groups) because the case numbers (maximum of 100 for a sub-group) are too low, and the volunteers were not selected randomly from each population but due to their own interest to join the study. Moreover, most of the participants in the downstream population were selected because they manifested high Hg blood levels in similar tests conducted by other interested group.

	control	population down-stream	Mt. Diwata without occupational burden	burdened by family members	ball millers	amalgam smelters	other occupational burdened
total number	42	100	43	20	55	41	6
mercury intoxicated	0	38	10	7	36	35	2
% mercury intoxicated	0%	38.0%	23.3%	35.0%	65.5%	85.4%	33.3%

Table 3: Frequency of a chronic mercury intoxication

5.0 Recommendations

5.1 From Dr. O'Reilly (international medical/toxicology expert)

a. In any case of intoxication the first step must be a stop of exposure to the harmful toxin. Therefore mercury exposure has to be stopped or at least drastically reduced urgently in this area. This means a stop or a dramatic reduction in the use of mercury for the extraction of gold from the ore by the amalgamation technique. Considerable effort has urgently to be taken, to improve these working habits. Amalgam burning and gold melting in closed vessels is essential for a reduction of the mercury burden. A safer storage and handling of liquid mercury is urgently necessary, too.

b. A diagnostic and treatment unit for mercury intoxication should be established preferably in Monkayo Municipal Health Center.

c. Assess the mercury burden of local fish and all the fish along the Agusan river system down the bay of Butuan. Also the assessment of mercury in the local chickens, pigs and fruit plants in Diwalwal and in rice and other crops irrigated by Naboc and Mamunga rivers, is recommended.

5.2 From Dr. Don Appleton (international geochemistry expert)

a. From a practical point of view, there is no point in trying to remediate and rehabilitate the Hg contaminated waters and bottom sediments of the Naboc, Agusan and Hijo Rivers until (1) the releases of Hg contaminated mineral processing tailings from the Diwalwal area have been terminated, (2) the risk of future contamination of the drainage basins by progressive or catastrophic releases of Hg contaminated processing waste contained behind tailing dams has been eradicated.

b. The only effective option to prevent the continuing Hg pollution of the Naboc River system and surrounding agricultural areas is to require (1) zero discharge to surface waters and (2) that releases to ground water do not cause violations of drinking water standards.

c. The <u>cessation</u> or strict control of mineral processing activities at Diwalwal would lead to a significant reduction in the Hg-contaminated suspended sediment load and this would hasten the natural rehabilitation and re-population of the aquatic environment. Unpolluted sediment derived from soil run-off would progressively cover contaminated bottom sediment in the Naboc and Agusan Rivers, thereby helping to prevent further downstream transfer.

d. Prior to making any decision regarding the need for remediation and rehabilitation of river bed sediments, there is a requirement to assess the ecological exposure and effects of Hg in contaminated sediments through the use of sediment toxicity tests (i.e. field based biological effects tests and bioaccumulation test methods, as well as the determination of the chemical characteristics that influence bioavailability).

e. It is recommended that the ratio between methyl and total mercury in the suspended and bottom sediments be determined in order to derive an indication of the potential bio-availability and toxicity of the Hg

5.3 From Dr. Weeks (international terrestrial ecology expert)

a. To further assess the situation and determine risk exposure from all pathways including air, and if necessary review the exposure calculations after a more systematic data collection exercise and reassessment of exposure from different food types in particular fish and livestock.

b. One further recommendation might be (pending further analysis) that the rice stalks which are known to accumulate significant concentrations of heavy metals should be removed from the paddy field rather than ploughed back in (green manuring).

5.4 General Recommendation

The awareness of ball millers, smelters and gold buyers' associations regarding the dangers involved in the use of mercury should be sharpened through further extensive educational campaigns and training in the proper use of mercury and its recovery/recycling. The mineral processing activities should be relocated to designated Mineral Processing Zones where properly engineered tailings impounding systems are to be constructed.

References

Appleton, J. D., (2000). A study of the extent of mercury and related chemical pollution along the Naboc River, Monkayo, Davao del Norte; Hijo River, Apokon ore processing site; and their neighbouring areas (rice fields and banana plantations) A report for UNIDO Project DP/PHI/98/00511-02, British Geological Survey, 108 pp.

Böse-O'Reilly, S., Maydl, S., Drasch, G., Roider, G. (2000). Mercury as a health hazard due to gold mining and mineral processing activities in Mindanao/Philippines. Final report, UNIDO Project DP/PHI/98/005, Institute of Forensic Medicine, Ludwig-Maximilians University, Munich, Germany.

Jung MC, Thornton I (1997). Environmental contamination and seasonal variation of metals in soils, plants and waters in the paddy fields around a Pb-Zn mine in Korea. SCIENCE OF THE TOTAL ENVIRONMENT, 198, 105-121

Kijewski H (1993) Die forensische Bedeutung der Mineralstoffgehalte in menschlichen Kofhaaren. Schmidt Römhild Verlag, Lübeck, Germany

Lee, J.S., Klinck, B., Moore, Y. (2000). Dispersal, risk assessment modelling and bioavailability of arsenic and other toxic heavy metals in the vicinity of two abandoned mine sites in Korea. Report by the British geological Survey. Fluid Processes and Waste Management Series Technical Report WE/00/1.

Lockowandt O (1996) Frostigs Entwicklungstest der visuellen Wahrnehmung.
Weinheim: Beltz

Masur H, Papke K, Althoff S, Oberwittler C (1995) Skalen und Scores in der Neurologie. Thieme, Stuttgart

Weeks, J. M. (2000) A study of the potential risks to human health from consumption of rice cultivated in paddy fields irrigated by mercury-contaminated mine waste water, Naboc River, Philippines, UNIDO Project DP/PHI/98/00511-03, Centre for Ecology and Hydrology, Monks Wood, Abbots Ripton, Huntingdon, Cambridgeshire, United Kingdom

Williams, TM, Weeks, JM, Apostol Jr, AN., CR Miranda (1999). Assessment of mercury contamination and human exposure associated with coastal disposal of waste from a cinnabar mining operation, Palawan, Philippines. ENVIRONMENTAL GEOLOGY*, 39, (1) 51-60*

Zimmer R, Volkamer M (1984) MOT - Motoriktest. Beltz, Weinheim

Zhang ZW, Watanabe T, Shimbo S, Higashikawa K, Ikeda M (1998b). Lead and cadmium contents in cereals and pulses in north-eastern China SCIENCE OF THE TOTAL ENVIRONMENT, 220, 137-145