Mercury poisoning:
A Threat to Brownsweg Villagers

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1.   INTRODUCTION

The use of mercury in small scale gold mining activities has been increased exponentially in the last two decades. Mercury is being added to a mixture of ore and other material to form an amalgam. In this way the gold can be easier extracted. The gold is being released from the mercury by heating the amalgam. By doing this, almost 70 % of the mercury will be released by vapor. 20% will be discharged with the tailing to creeks and rivers (Veiga, 1997). This will lead to enormous discharge of mercury to the environment. In the environment, mercury (Hg°) is being oxidized to inorganic mercury, which can be methylated by micro-organisms and or photochemical processes (for example humus acids) (Morel et al, 1998). Methyl mercury is very toxic, can easily be absorbed by organisms from the lower levels of the food chain and accumulated in the highest level of the food chain, e.g. predatory fishes. By eating predatory fishes polluted with mercury, human can be exposed to mercury poisoning. Methyl mercury can affect the human body negatively, especially the nervous system. Symptoms of mercury poisoning are very vague and can be seen after months. Adults can show symptoms as ataxia, paresthesias, malaise and decreasing sight, smell and taste. During pregnancy, the nervous system of the unborn child can also be affected through the placenta. Babies can be affected by breast feeding. Damages done to the brains of babies lead to symptoms as deafness, bad sight, blindness, microcephally, cerebral palsy and problems with swallowing (Pope et al, 1995).

Results from fish consumption studies on tribal communities in the Amazon showed that there is a positive correlation between the consumption of fish polluted with mercury and mercury concentrations measured in human hair. In the communities of the Duas Bocas in the Amapa State in Brazil, where fish is the main part of their diet and the community is directly affected by gold mining activities, mercury levels of 28 µg/g were found in human hair. Mercury levels in hair of the Wayana population in French Giuana showed that 57.4% of the measured hair samples were above the safety limit of 10 µg/g (WHO). The highest concentration measured was 27.2 µg/g (Fréry et al, 2001).

During the project 'Monitoring of Mercury Pollution in the Greenstone Belt', an inventory was made of the mercury pollution in the gold mining areas and the impact on downstream locations. Areas that are most affected by the gold mining activities were also identified. In one of the gold mining areas, Nieuw Jacobkondre, a pilot fish consumption study was done to find a relation between fish consumption and mercury concentration in human hair. In a reference site, Poesoegroenoe, which is not a gold mining area and is located upstream of Nieuw Jacobkondre, the same study was carried out. From the results of the study in Poesoegroenoe a positive correlation was found between mercury concentrations in hairsamples (2.08 – 12.11

μg/g) and the consumption of especially predatory fish. It could be assumed that these fishes were probably polluted by mercury from atmospheric transportation from the northeast (Ouboter et al, 2007).

Another location that has been negatively affected by the gold mining activities is the Brokopondo Lake. Results from the inventory of areas polluted by mercury shows that the Brokopondo Lake is the most polluted area in Suriname. The following concentrations have been measured in the Brokopondo Lake:

	Water	Sediment	Fish
Dry season 2005	0.11		
Dry season, average 2004/2005		0.27	1.5
Rainy season, average 2004/2005	0.28	0.2	1.16

Table 1. Overview of mercury measurements in the Brokopondo Lake

The measured concentrations are above international standards for mercury in freshwater organisms (0.1 μg/l), in sediments (0.14 μg/g) and for human consumption (0.5 μg/g).

Several villages are located around the Brokopondo Lake with Borwnsweg as the biggest at the northwest of the Lake. The water of the Lake is being used by the villagers as drinking water, after it is biological purified by a sand filter. Their most important protein source is fish and is also caught from the Lake. Species that are mostly caught are piranha (*Serrasalmus rhombeus*) and tukunari (*Cichla ocellaris*). It is expected that by eating polluted fish from the Lake, mercury is being taken up by the human body. For the effects of this chronic mercury poisoning, see above mentioned symptoms.

The project carried out aimed to provide an overview of mercury levels in the community and create awareness about possible chronic mercury poisoning in the Brownsweg village. Fish consumption was surveyed and linked to mercury levels in hair. In addition neurological and neuro-psychological tests were performed and correlated to mercury levels in hair. To be able to provide advice on alternative fish from the lake that are safe for consumption, fish surveys were carried out in the lake and mercury levels analysed.

2. METHODOLOGY

The study was conducted at the Brownsweg villages in the district Brokopondo. There are nine (9) villages in the Brownsweg community: Biri-udu-matu, Kdayu, Nyun Gansee, Dyankakondre, Makambi(kreek), Wakibasu I, Wakibasu II, Wakibasu III en Wakibasu IV. From the last held census in 2006, there was an estimate of 1462 villagers in the Brownsweg area. The study was implemented as follows:

2.1. Approval request

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- A request to execute the project was sent to the Minister of Health
- The District Commissioner of Brokopondo was informed about the project and asked for approval
- An information session was held with the heads of the Brownsweg community, the health sections in the area (Regionale Gezondheid Dienst, etc) and key persons for example teachers from the area. They were informed about the activities of the project and consensus was reached about the project goals.

2.2. Preliminary research

An inventory was madeof all households in the Brownsweg community. Based on the household inventory, the households were selected by a purposive sample selection to participate in the fish consumption survey. The criteria for the selection were:

- Household consisting of the sensitive groups: pregnant women, mothers that gave birth within the last three months and children between 6 and 12 years
- Household with members that have stayed at least 5 years in the village
- Households that are willing to participate

To get an overview of the accumulation of mercury in the villagers, the villagers of the selected households were divided in age classes. Depending on the participation, a random sample of people in the different age classes was selected to provide hair for the mercury analyses.

The selected persons were also asked for permission to be examined on neuro-behavioral functions.

2.3. Execution of the surveys

The whole study was carried out in four parts:

a. The fish consumption pattern. By making an inventory the following was registered for each household member:

   i. Name
   ii. Sex
   iii. Age
   iv. Weight
   v. Profession
   vi. Residence time in the area
   vii. Health status (health problems)
   viii. Information about fish consumption patterns. During two weeks the following information was registered for each selected household:
   1. Consumed fish species
   2. Fish resources (from Paramaribo, the Brokopondo Lake or elsewhere)
   3. Amount of consumed fishes
   4. Size of consumed fishes (length measurements)
   5. Weight of consumed fishes per selected household member
   6. Other protein sources
   7. Pregnancy (for women)

b. Collecting of hair samples for mercury measurements.
   Hair samples were collected by taking a three inch long cluster of several hair strands. The hair was being held with a hemostat and cut at scalp from the occipital area with stainless steel scissors, secured with dental floss. The sampled hair was stored in appropriately labeled polyurethane bags (State of Alaska Dept. of Health, 2002)

c. Neurobehavioral examination.
Several neuro-psychological tests were selected based on results in the literature (Grandjean et al., 1997; Lebel et al., 1997; Grandjean et al., 1999; Drasch et al., 2001; Cordier et al., 2002; Marques et al., 2007) to measure the following functions: Motor function (fine motor performance, coordination, motion sequence), visual function, verbal function, tactile processing, attention and memory.

d. Fish survey. From the Lake fish was caught and analyze on mercury to get a good overview of the accumulation of mercury in fish. The information gathered was used to find species that are low in mercury accumulation and are good for consumption.

The whole study was carried out in two periods: rainy season and dry season because consumption patterns may be different in both seasons. During the dry season more predatory fishes may be eaten than in the rainy season (Ouboter et al, 2007).

2.4. Mercury analyses

All mercury analysis was carried out in the laboratory of the NZCS/CMO with a dedicated mercury analyzer using the cold vapor atomic absorption technique (Clesceri et al. 1998).

2.5. Data analyses

Data analysis was carried out using Student t-statistics and regression analysis

2.6. Awareness

The goal of the project is to create awareness among the villagers of Brownsweg regarding chronic mercury poisoning through fish consumption. The awareness program of the project included the following activities:

- Before the start of the surveys, the villagers were presented general information about mercury poisoning through fish consumption. The relevancy of the subject to their situation was also presented together with the aim of the project
- Final project results presentation. The proposed strategy for healthy fish consumption will be presented to them. Ways to implement this strategy will be discussed with them

2.7. Ethical issues

The research objectives of this project require full participation of the Brownsweg community and answering of all the questions that will be asked. This means that before starting the project, the researchers will have to seek consent from the participants. This can only be done if the participants understand the goals of the project. As stated in the section 'Awareness', the Brownsweg community will be informed about the aims of the project before the start of the study. After that each household will be asked if they want to participate in the study. After the study has been conducted, households that have participated successfully in the study will receive a small incentive for their participation.

3. RESULTS

3.1. Selection of households

During this study, households from the following villages participated in the study: Wakibasu II (7), Nyun Gansee (9), Djanka kondre (3), Kadyu (9), Wakibasu I (7), Biri-udu-matu (6), Makambi (9), Wakibasu III (2). In total 137 women and 35 men participated in the survey, in the

age interval from 3 months to 55 years. Figure 1 gives the ages frequency of the participants during this study.
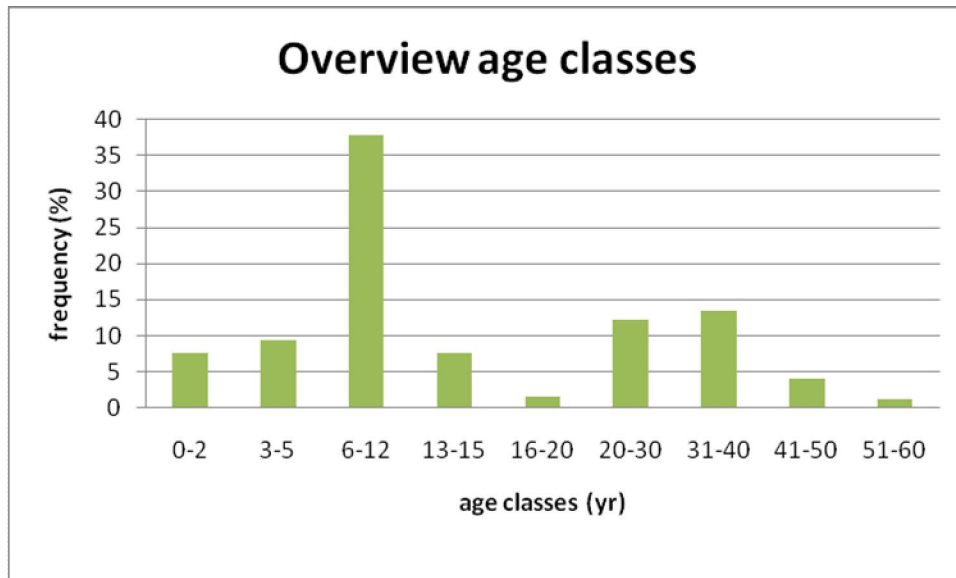

Fig 1. Overview age classes of participants during the fish consumption survey

3.2. Fish consumption

During 6 days of both survey 1 and 2, the fish consumption of participating households were registered. Table 2 shows the result of the fish consumption analysis from the 6 days registration. Fish does not seem to be the main protein source in the villages. Respectively 84% and 74% of the meals registered during the 6 days did not include fish. Participants use other protein sources, for example chicken in their diet. When fish is included in the diet, this comes mostly from Paramaribo (registered in resp 8.86% and 18.30% of the meals). Fish species from Paramaribo which are mostly consumed are: Wit-witi (*Cynoscion* sp.), red snapper (*Lutjanus purpureus*), botervis (*Nebris microps*), barracuda (*Sphyraena barracuda*), barbaman (*Bagre bagre*), kandratiki (*Cynoscion virescens*), so mostly brackish water and marine species. Only 4.80% and 5.10% of the meals registered included piscivorous fish from the Lake, which included piranha (*Serrasalmus rhombeus*) and toekoenari (*Cichla ocellaris*).

	Survey 1	Survey 2
No fish in the meal	**84%**	**74%**
Fish in the meal	**16%**	**26%**
Piscivorous fish from the lake	4.80%	5.10%
Piscivorous fish from other location	0.70%	0.64%
Non-piscivorous fish from the lake	0.70%	1.60%
Fish from Paramaribo	8.86%	18.30%
Unknown fish	0.70%	
Non-piscivorous fish from other location		0.30%

Table 2. Results of fish consumption analysis

3.3. Mercury analysis of hair samples

Mercury concentrations were measured in hair samples from the villagers. Figure 2 shows the frequency of mercury concentrations measured. Table 3 shows the average mercury concentrations for men, women and children (6-12 yr) for survey 1 and 2. There is no significant difference found in mercury concentrations between survey 1 and 2, when data for both men and women are pooled together (t-test, df=116, p=0.809).

During the first survey hair samples were taken from two pregnant women and resulted in respectively 0.8 and 3.5 µg/g. During the second survey the mercury concentration of 3.5 µg/g measured in one pregnant woman had dropped to 2.26 µg/g.

	[Hg] survey 1 (µg/g)	**[Hg] survey 2 (µg/g)**
Women	2.08 (N=132)	3.08 (N=35)
Men	2.05 (N=114)	1.68 (N=15)
Children (6-12 yr)	2.02 (N=94)	1.98 (N=74)

Table 3. Average mercury concentration in hair samples from participants
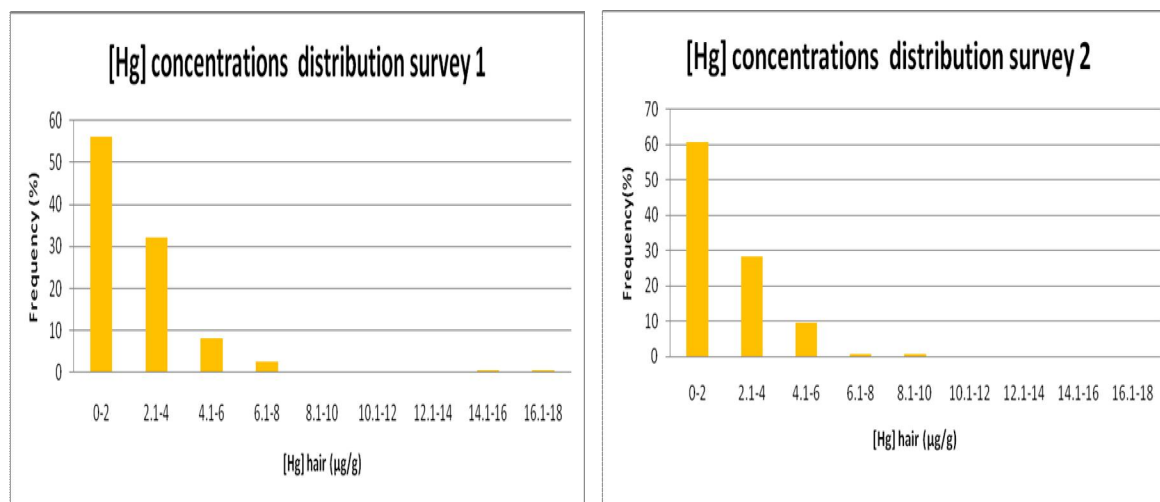
Fig 2. Distribution of mercury concentrations measured in hair samples from participants during survey 1 and 2

Only two participants had mercury concentrations higher than the NOAEL level (10 μg/g): man (40 years): 16.24 μg/g and woman (31 years): 14.15 μg/g.

Villagers consuming fish, contaminated with mercury, on the long term are expected to have high mercury concentrations in their hair. To find this relationship two parameters, living time in region and age, are regressed against the mercury concentration measured in the hair samples. It is expected that participants who live longer in the area and are older, will have consumed more contaminated fish, resulting in higher mercury concentrations in their hair. Significant but weak relationships have been found for the relation between time in region and mercury concentration ([Hg]= 0.027*Time in region +1.853, r^2= 0.068, p=0.032) and for age and mercury concentration ([Hg]=0.032*Age + 1.752, r^2=0.208, p=0.008). These weak relationships are probably due to the fact that the participants do not eat that much piscivorous fish from the Lake.

3.4. Mercury levels of fish species in the lake

Fig. 3 gives the results of the mercury analysis done of fish caught in the Lake. As expected mercury levels are highest in piscivorous and lowest in the only herbivore *Myleus rubripinnus*. Detritivores are also low and omnivores intermediate. Of the omnivores *Leporinus* sp. is on average above the EU standard for human consumption of 0.5 μg/g. Three of the piscivores are above this standard *Serrasalmus rhombeus* (average:1.61 μg/g) , *Plagioscion* sp. (0.69 μg/g) and *Acestrorhynchus guianensis* (average 1.71 μg/g). The Toekoenari (*Cichla ocellaris*) is on average below the standard for human consumption. Of the piscivorous species *Serrasalmus*

rhombeus has been registered the most in meals during the survey. *Plagioscion* sp. and *Cichla ocellaris* are also favorable consumption fish. Non-piscivorous fishes seem to be not attractive for the villagers to eat.
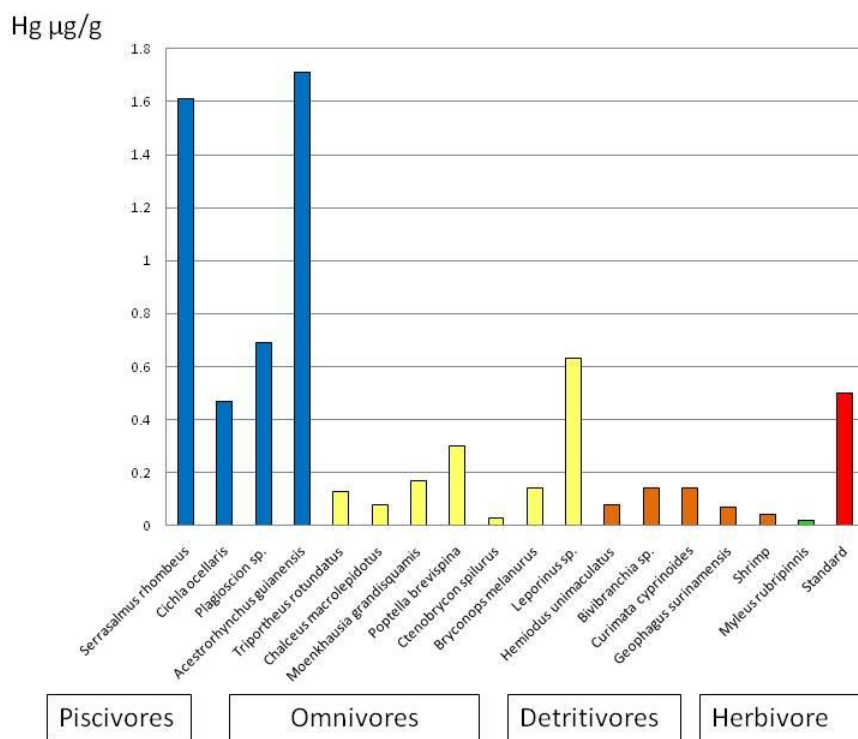

Fig. 3. Mercury concentrations measured in fish species caught in the Lake

3.5. Mercury intake

Because it is usually impossible to measure the percentage of a fish being eaten by a household and the percentage eaten by each member, fish consumption data was generally too limited to calculate the mercury intake of all participating household (members). This could be done for only one household (intake per household member was 0.57 μg mercury per gram fish). This household consumed a piranha (*Serrasalmus rhombeus*) with a length of 20 cm.

4.   CONCLUSIONS

- Villagers of the Brownsweg area do not depend only on the Lake for protein intake.

- This resulted in low mercury concentrations measured in hair samples of the participants.

- Still, piscivorous fish species (who have high mercury concentrations) from the Lake seem to be preferred by the villagers which may still pose the danger of mercury poisoning among the Brownsweg community.

- The people prefer to eat the larger fish species. Most omnivores and detritivores, which are low in mercury, are small in size. Most larger fish species are piscivores. Of these the Piranha (*Serrasalmus rhombeus*) and *Acestrorhynchus guianensis* have very high mercury levels and should be avoided as food. Larger fish species with mercury levels far below that of the two species mentioned are:

  o The herbivorous *Myleus rubripinnus* (Pakoesi) has very low mercury levels

- The piscivorous *Cichla ocellaris* (Toekoenari) has average mercury levels just below the standard for human consumption

- The piscivorous *Plagioscion* sp. (Koebi) has average mercury levels just above the standard for human consumption.

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