# Prey Meas Goldmine, Ratanakirri, Cambodia
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**Abstract**
Mercury is used to extract gold in simple gold mines in Ratanakirri province, NE Cambodia. Before introduction of retorts, the gold amalgam was heated with an open flame to volatilize mercury and recover gold. The process resulted in release of mercury and elevated mercury levels in the hair of gold workers handling mercury. Fifty kilometers downstream hair levels of villagers was significantly higher than the average gold worker and above levels associated with the first signs of mercury poisoning. Fish collected close to the mine did not have high mercury levels but 50 km downstream mercury in large predator fish was as high as 400 ng/g. If the mine wastes were the major source of mercury, methylation of mercury near the mine must be suppressed by mine effluents. Retorts were successfully introduced to recycle mercury at the goldmine.

**Introduction**
Artisanal gold mining results in about one third of atmospheric mercury pollution. Thus, the need to improve the extraction of gold is at least a regional if not a global concern. Once mine sites are contaminated, restoration is difficult if not impossible in the third world. Moreover in Cambodia, the rivers receiving mercury wastes are targeted to have hydroelectric dams (Figure 1). Typically reservoir construction results in enhanced methylation of mercury, increased bioaccumulation of mercury and as much as a 1000 fold increase in mercury toxicity.

In Cambodia, most goldmines are in the east and north. The goldmine studied in this report is Prey Meas in Ratanakirri province in NE Cambodia. Sotham (2004) states that in his survey in 2003, there are six active mining sites in Prey Meas gold deposit: Bay mot; Bay Hai; Bay Ba; Bay bon; Prey Meas; and Prey Thmei. Specific GPS coordinates are not available for all the mine sites and miners also refer to other mines in the area. Miners informed us that the Prey Meas shafts (within the Prey Meas complex) are now abandoned. Prey Thmei is the only mine site that was sampled in this study. The common practice is to still call the Prey Thmei mine "Prey Meas" and to avoid confusion we will continue to use this term. Sotham (2004) estimates that in the dry season the number of miners increases by several hundred. A census was not done, would be difficult, and the important variable is the number of flumes, not workers.

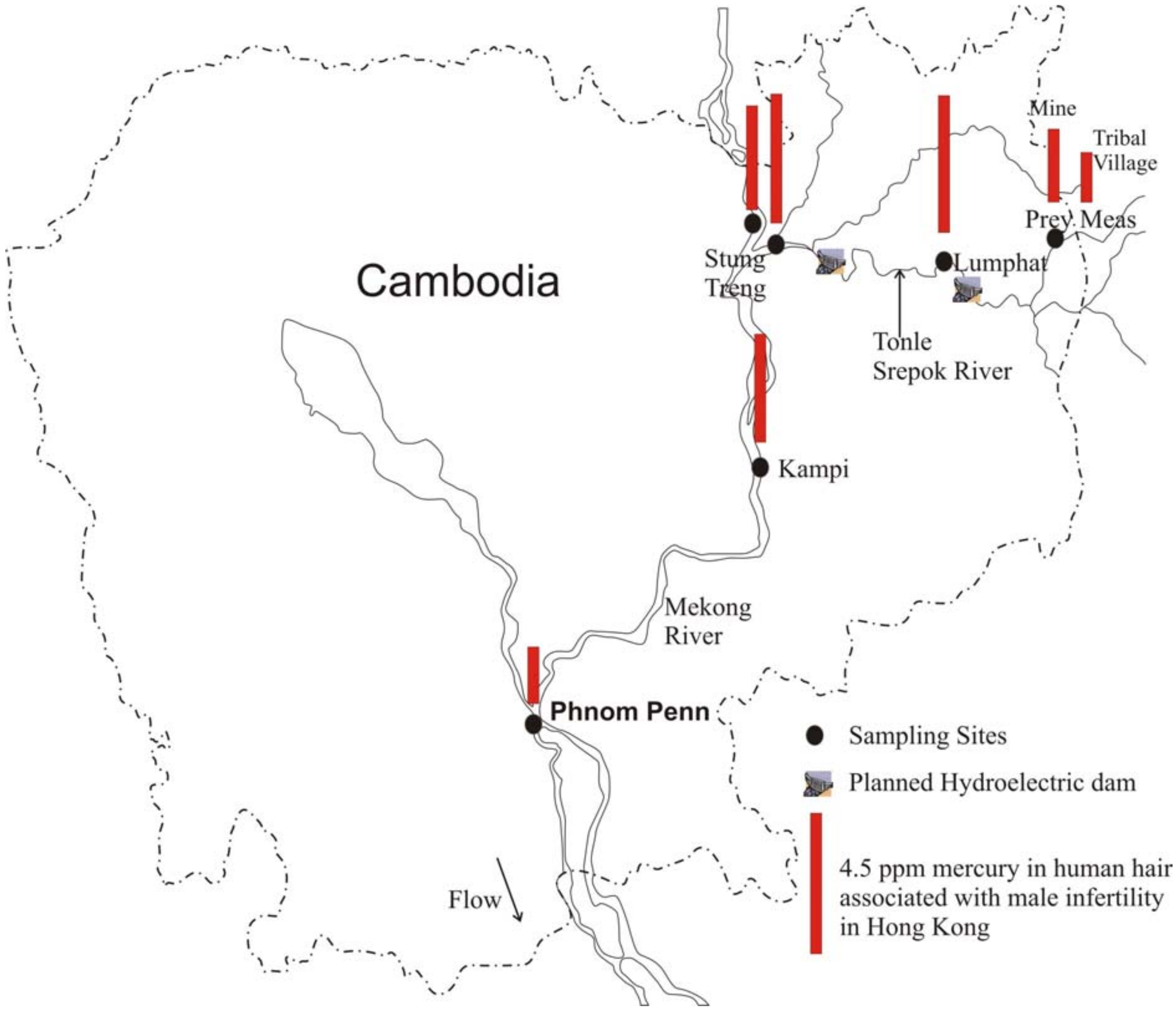


Figure 1. Map of Sampling Sites

**Methods**

The goldmine site (13°31'22.9" N, 107 22'46.6" E) is in a dry forest about 48 km SE from Banlung. Miners use motorcycles to access the mine. Even when dry, the road access is extremely bad requiring a four wheel drive vehicle with high clearance and a skilled driver. Either off duty policemen or military men were used for drivers. Security was mentioned as a concern in Sotham (2004). Some miners might present risks and some danger could be associated with illegal logging. Trees in various state of being processed were seen but no loggers were visible. We had talked to many drivers and likely everyone with good vehicles knew of our presence.

## Mercury Analysis

For most mercury analysis, a DMA80 Direct Mercury Analyzer from Milestone was used. The process is detailed in EPA Method 7473: Mercury in Solids and Solution by Thermal Decomposition Amalgamation and Atomic Absorption Spectrophotometry. This process is designated for the determination of total mercury in solids, aqueous samples and digested solutions. Solid and aqueous samples are dried and then thermally and chemically decomposed by controlled heating in an oxygenated decomposition furnace to liberate mercury. The decomposition products are carried by flowing oxygen to the catalytic section of the furnace where oxidation is completed and halogens and nitrogen/sulfur oxides are trapped. The remaining decomposition products are then carried to an amalgamator that selectively traps mercury. After the system is purged with oxygen to remove any remaining residual by-products, the amalgamator is rapidly heated to release mercury vapor. The vapor flows through an atomic absorption spectrophotometer set at 253.7 nm to measure the concentration of mercury. Certified reference materials (CRM) were used for each set of analysis. Results were always within the standard deviation of the CRM. Relative standard deviations were typically around 3%. Blanks were run for each set of analyses and blank values were always much less than 1% of samples.

Drinking Water Analysis

One well with a depth of about 30 m serves the mining community with drinking water. Cyanide in the well water, before and after filtration, was measured using a colorimetric procedure (1NW6) in the Wastewater Technology Centre, an accredited laboratory within Environment Canada. Environment Canada's accredited National Laboratory for Environmental Testing (NLET) analyzed metals and major ions in the well water.

Coliscan kits were used to evaluate bacterial contamination (www.microbiologylabs.com). One ml of water was added to the culture media, swirled, then poured into the culture plates and incubated for 36 hours prior to counting. This procedure is simple but is approved by various American agencies such as the Virginia Department of Environmental Quality for screening purposes. Confirmation analysis was not possible in this study.

Hair samples

Hair samples were collected from miners March 7, April 1 and April 20 (Figure 2). Also hair samples were collected from a village on the Ou Tran River, approximately 6.1 km from the mine (13°31’51.0” N, 107°26’27.0” E). Figure one includes data from early sampling (Murphy et al. 2006). In general, no treatment of hair was done prior to analysis. Some samples were washed with deionized water and the washing had no effect on the mercury content.

Figure 2. Collecting Hair Samples

Fish sampling

It was difficult to access the Ou Tran River that receives drainage from the Prey Meas goldmine. Note that spelling of translations varies widely and some maps show the Ou Tran River as Prek Drang. Dirt paths allowed access to the river from the goldmine by motorcycles. We got to within a few kilometers of the anticipated drainage of the mine to the river. On April 20, two men with a simple net (2 m by 10 m) were not able to collect fish (13°31'51.0" N, 107°26'27.0" E). On April 22-23, a small boat was later used to go 48 km up the Srepok River to collect fish 1 km up the Ou Tran River (13°19'35.1" N, 107°20'51.6" E). Five species of fish were collected from the Ou Tran and another 15 species were collected from the Tonle Srepok but no large predator fish such as the snakehead were sampled. April 24, snakeheads were collected from the Tonle Srepok River by fisherman and bought at the market in Banlung. Identification was done using the FAO Fishes of the Cambodian Mekong (Rainboth 1996).



## Results

The goldmine has enough mature trees that aerial photography might not be useful to measure the extent of mine tailings. The bedrock is overlaid with about 2 m of soil. The gold bearing rock is found in veins that are removed with explosives. The shafts are not supported with timber. The rock is ground and feed into hydraulic flumes (Figure 3). The wastes from the flumes are not treated in any way. There is no attempt to contain the mine tailings (Figure 4). The mercury content of two mine tailings samples was 7734 and 7697 ng/g. Likely this mercury eroded from the flume but it could have reflected mercury volatilized when the amalgam was heated.

Figure 3. Flumes for Gold Recovery (hose at right was used to reveal mercury)

Figure 4. Mine Tailings –left Prey Meas right O Tron mines, Cambodia

The active components of the flume are metal sheets that are covered with a layer of mercury to trap the gold. At the end of the day, the gold amalgam is scrapped off the metal sheet (Figure 5). The first next purification step is the squeezing of the unreacted mercury through a cloth. The gold amalgam does not pass through the cloth. Next the miners heat the gold amalgam with an open torch on a piece of clay pottery until the mercury vaporizes (Figure 6). At this point, the gold still has obvious black specs and is impure. Next the miner adds about 10 times the mass of silver to the gold with nitric acid. The acid is then heated until it boils (Figure 7). The resulting solution is then dumped onto the ground. The acid is then flushed with water. The resulting gold looks pure.

Figure 5. Scraping Mercury off Metal Flume

**Hg recovered in retorts**

First, one retort was made in Canada as a model for local craftsman in Cambodia (Figure 8). The "Canadian" model was constructed from kitchenware utensils that originated from China. As expected, similar products were available in Cambodia. The stainless steel in these products is thin but welders in Canada and Banlung had no difficulty making the required modifications. Heating with a small stove was not effective (Figure 9). A hand-held torch directed the heat to the gold better and not to the overlying water trap (Figures 10, 11). The cost of the retort in Banlung, including labour was $10.50. Mercury was effectively trapped in the retorts (Figure 12). The miners preferred the glass top retort that was only intended for demonstration. Two retort designs were used successfully. A glass jar was also evaluated but the flat top condensed too much water which dropped into the recess with the mercury. The shape for the top must be curved.

Figure 6. Heating Amalgam to Volatilize Mercury and Recover Gold

Figure 6 shows the process that was used before the introduction of retorts. The heating of mercury in the open contaminated the workers, their families and everything downstream. As well as the training at the mine site and demonstrations were given to the local Ministry of Environment and craftsmen in Banlung. Presentations were given in Phnom Penh to the Ministry of Environment, Ministry of Fisheries, Plan International, and Rotary Club.

Figure 7. Heating Nitric acid and Silver to Purify Gold

Figure 8. Retort

Figure 9. Retort with Cooking Heater

Figure 10. Retort Demonstration

Figure 11. Closeup of Heating Retort

Figure 12. Retort After Separation of Mercury and Gold

**Mercury in Human Hair**

The assimilation of mercury into people and conversion into methyl mercury can be measured easily in human hair. In Figure 1, the pattern of mercury is clear. About 50 km downstream of the goldmine, human hair has on average slightly more mercury that Dickman et al. (1998, 1999) found in Hong Kong to be associated with fertility problems in men. It is also much higher than the average reported (0.99 ppm) to be associated with health impairment of gold workers in the Philippines (Akagi et al. 2000). Individuals (not mean) exceed levels associated with lose of peripheral vision (Barbeau et al. 1976), early nervous system dysfunction (Lebel et al. 1998) or child development (Barbosa et al. 1995, McDowell et al. 2004). Further downstream before the junction with the Mekong River the levels decrease slightly but are higher than Kratie and drop much more in Phnom Penh.

The lower mean mercury contamination in hair at the mine seems strange but the data reflects two aspects. One, the average (n=9, 2.33 ppm) was brought down by three workers who only dug rocks (mean 0.69 ppm) and likely were not at the mine long. Two, the miners are isolated from the river and do not eat much fish. Not shown in Figure 1 is a data set that further complications the analysis. Nine tribal villagers 6.1 km from the Prey Meas goldmine had a mean of 1.58 ppm ( ±0.34) of mercury in their hair. There is some uncertainty about the route of drainage from the mine but they fished in the area of the mine drainage. The lower content of mercury in their hair could reflect the following:

1) Tribal people traditionally lived in the forest and had a different diet from Khmers. They do eat fish but their diet could influence assimilation of mercury.
2) The fish in the river at the village had less mercury or there were fewer large predator fish. Both seem possible but the data is too modest for certainty.
3) Toxins from the mine or some other factor suppressed methylation of mercury and there was less bioaccumulation. Once the tributary joins the Tonle Srepok River, dilution of toxins would be at least tenfold perhaps then enabling methylation of mercury.
4) The pattern of mercury contamination might reflect another source of mercury such as atmospheric, such as from deforestation (Veiga et al 1994).

**Mercury in Fish**

Fish is readily available along the river, but in Phnom Penh, fish is more expensive than pork or chicken, the city dwellers eat less fish, and bioaccumulate less mercury. Large predator fish such as snakeheads contain more mercury (400 ng/g) than is generally recommended for pregnant women (Figure 13). Concentrations of mercury were highest in a set of samples from Lumphat collected in February 2006. Lumphat is more than 50 km from the goldmine. Nineteen samples had a mean of 149 ng/g of mercury (Table 1, Appendix). Six of the predator fish had more mercury (200 ng/g) than Health Canada (1978, 1984) has recommended mercury in subsistence settings where people consume a lot of fish. The predator fish are more popular. Health Canada's advisories suggest that 1 kg of the average fish in Lumphat could be eaten safely in a week (Health and Welfare 1984). Some people would exceed this amount of fish.

Figure 13. Predator Fish like these Snakeheads are Richest in Mercury

Like with the hair data, closer to the goldmine, the mercury content of fish is lower. On April 22, eight fish collected from the Ou Tran River had a mean of only 16 ng/g of mercury. Between the Ou Tran River and Lumphat 20 fish had a mean of 54 ng/g, much less than the fish from Lumphat in February. The fish data show in Figure 14 has the same pattern as the human hair analysis. It would be difficult to collect enough of the same fish species and same size to confirm statistically the pattern that is statistically strong in human hair. The bioaccumulation of mercury appears to be suppressed close to the mine, and near the mine, mercury is not likely being methylated.

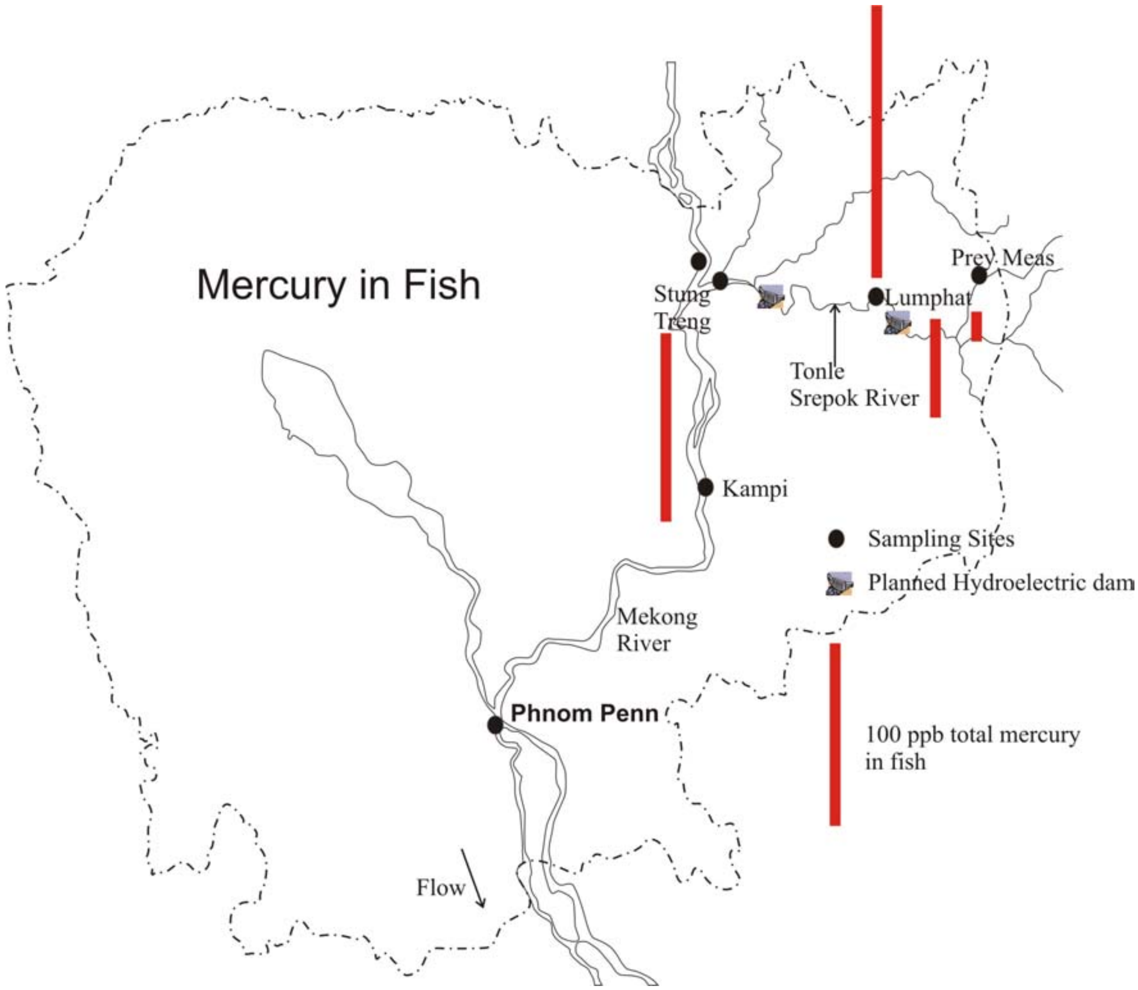


Figure 14. Mercury in Fish

**Sanitation**

The mine site had no toilets. Furthermore dogs, chickens and pigs roamed freely. Diarrhea and malaria were common. No assessment of parasites or disease has been conducted. The Coliscan analysis indicted that the drinking water well was contaminated. The miners did not always boil water. The RDI filter effectively removed the bacteria and likely other parasites (Figure 15, Table 2). The free roaming pigs could be a source of Giardia and Blastocystis. The filtered water smelled, looked and tasted good. Cyanide in the well water was detected at 0.002 mg/L. The maximum acceptable concentration for cyanide in drinking water is 0.2 mg/L (Ontario 2003). Cyanide was not leaking from the cyanide leaching tanks (for gold extraction) into the well water and cyanide was not a problem in their well water. Further analysis indicates that other aspects of the water quality of the well water are acceptable (Table 3).

Table 2 Well water bacteria [per ml]

| Colony Type | F-1 | F-2 | Raw-1 | Raw-2 |
|---|---|---|---|---|
| E. coli | 0 | 0 | 6 | 4 |
| Unidentified | 1 | 0 | 12 | 80 |
| General coliforms | 0 | 0 | 41 | 75 |

F-1 and F-2 and samples that were processed in the RDI ceramic filter.
Raw-1 and Raw 2 are samples that were not filtered by the RDI ceramic filter.

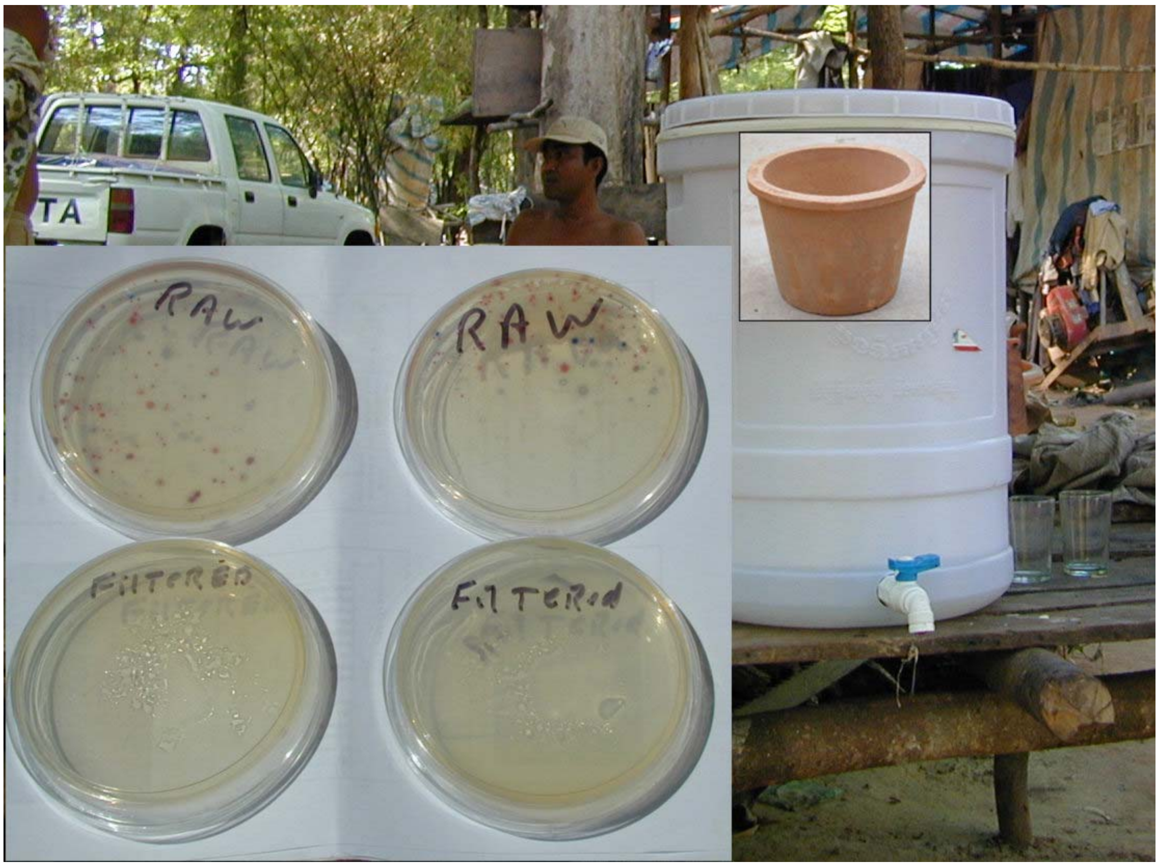


Figure 15. Ceramic Water Filter Removed Bacteria from Well Water

Table 3 Metals in Prey Meas Mine Wellwater (ppb)

| Metal | Concentration |
|---|---|
| Ag | 0.034 |
| Al | 193. |
| As | 2.51 |
| B | 0.7 |
| Ba | 216. |
| Be | 0.017 |
| Bi | 0.018 |
| Cd | 0.473 |
| Co | 2.47 |
| Cr | 0.084 |
| Cu | 1.56 |
| Fe | 1850 |
| Ga | 0.034 |
| La | 0.226 |
| Li | 4.9 |
| Mn | 492. |
| Mo | 0.138 |
| Ni | 0.90 |
| Pb | 5.35 |
| Rb | 2.39 |
| Sb | 0.030 |
| Se | 0.21 |
| Sr | 51.1 |
| Tl | 0.008 |
| U | 0.0030 |
| V | 0.707 |
| Zn | 31.8 |

Table three continued, Major Ions in Prey Meas Mine Wellwater (ppm)

| | |
|---|---|
| Cl | 2.07 |
| $SO_4$ | 32.6 |
| Ca | 56.6 |
| Mg | 11.4 |
| Na | 10.8 |
| K | 9.53 |
| $SiIO_2$ | 57.4 |

**Turbidity Downstream**

Figure 16 illustrates the extremely high turbidity in the river receiving drainage from the goldmine. The rocks in the stream were covered with a layer of ground rock. Although no measurements were made, it is highly likely that this turbidity suppressed periphyton (attached algae), invertebrates and in turn fisheries (especially spawning). Tribal children swam in the rivers with high turbidity from the mine.

Figure 16. High Turbidity in Ou Tron River Downstream of Goldmine

## Suggestions for Further Analysis

**Estimate of Mercury Flux from Goldmines**
It is important to estimate the flux of mercury from the goldmines. Several aspects need to be resolved before a good calculation is possible. The number of flumes being used, pumping rate of flume pumps, and the number of mines is not well documented. GPS readings are not available for most mines. One website claims that 15-20% of the mercury in a flume can escape (Gold - LoveToKnow Watches.htm ). Impressions from our April study indicate that less than 10% of the mercury used in a flume actually formed an amalgam to be recycled in a retort. Even with a full conversion to use of retorts, some mercury will be lost from flumes.

**Silver Used to Purify Gold**
The miners use silver to purify gold and then dump the silver rich solution. Silver is very toxic to fish and other aquatic animals (Silver 2003). In the USA, water with more than 3 ppm of silver cannot be flushed down a drain. Silver costs about $14 an ounce and recovery methods are available. As with the retort for mercury recovery, it is critical to provide miners with a simple system they can use for profit. Unlike with mercury, recycling silver will not likely protect the health of the gold miners but still it should be evaluated.

The following process is used in Ecuador to recover silver (Veiga, personal communication)

1. melt gold and pour it in water - the higher the height the better to obtain fine grains of gold
2. leach with $HNO_3$ (this will dissolve Ag and Cu)
3. filter and have gold in a brown powder
4. add NaCl in the solution (a fine white powder will precipitate - $AgCl_2$)
5. filter this powder
6. mix this powder with steel wool and use $HNO_3$ and water (50%)
7. a dark silver power will be precipitate - filter it
8. melt silver and pour into water to make beads (easier to sell)

**Alternative Methods of Gold Extraction**

Cyanide leaching tanks were observed but the process of cyanide extraction of gold was not part of this study (Figure 17). The miners that we worked with did not use cyanide. Not all miners were cooperative and to study the details of cyanide management would require time to find miners willing to consult. Furthermore other gold extraction methods such as bromide extraction could be evaluated as a replacement to mercury extraction. The miners believe that mercury extraction is the easiest method.

Figure 17. Cyanide Extraction of Gold

**Mine Tailings**

The volume of the tailings is uncertain and so is the erosion and downstream transport of mercury from the tailings. The retort is effective but it is still uncertain how much mercury escapes from the flume. The measurement of the mercury budget would require a sensitive balance and a method to remove water from the mercury. The alternative of shipping samples to a laboratory is awkward. A freeze drier seems unavailable in Cambodia and shipping mercury by air is restricted.

The sulfide concentration of the mine tailings is also important. As sulfides oxidize, sulfuric acid is formed. The acid is toxic and it dissolves metals converting innocuous minerals into toxic wastes. Important biological processes such as methylation of mercury are probably also impacted by mine wastes. Sulfide is known to suppression methylation of mercury (Steffan et al. 1988) and sulfides must be present in the volcanic rock. Also silver that is dumped from the gold purification is very toxic to bacteria (S. Silver 2003) and may well suppress methylation of mercury too.

Tailings management would partly reflect the sulfide concentration. Neutralization of sulfuric acid with base is highly unlikely at this remote site. Prevention of oxidation by placement of the tailings back in the mine or covering is technically possible but also unlikely. Construction of a tailings pond might enhance mosquitoes and malaria. Management of tailings would be much easier if the mine was managed by one operator not 30 independent families. There are many small tailings deposits.

The impact of the mine tailings could likely be best resolved with biological analysis of streams receiving mine wastes and compared to neighboring non impacted streams. Likely the biological diversity and potentially the productivity of streams are greatly suppressed.

**Impacts of River Turbidity**

Modern particle counters can quickly assess the size and shape of particles. Samples that were collected from the Mekong River were preserved and analyzed in Environment Canada laboratories; the preservative method worked well. This approach could distinguish turbidity associated with mine tailings from soil erosion. The alternative of taking turbidity readings with sensors exists but access to the rivers is difficult; it would be necessary to track each tributary. Satellite images might provide insight.

Furthermore, particle analysis should provide some insight into the fate of such materials in reservoirs that are planned downstream of the goldmines. Ideally, an assessment would estimate how quickly these reservoirs would be filled by mine wastes. The need for hydroelectricity is substantial and hydroelectric reservoirs are being developed quickly in neighboring Laos and Vietnam (Oxfam 2006).

**Malaria**

It would be interesting to determine if the common presence of malaria reflected the stress imposed upon the immune system by mercury (Crompton et al. 2002). Doing clinical evaluations of malaria with a kit like Malacheck$^{TM}$ would be a good humanitarian activity and perhaps provide basic scientific data. However, the optimal time for malaria is the rainy season when access to the mines is very difficult. The miners who own equipment stay at the mines throughout the year. We saw a very difficult place to live and in the rainy season, it must be particularly harsh.

**Comment on Health**

Assessments of the impact of mercury on malaria or some other health impairment such as loss of peripheral vision, or fertility would provide more reason for retrofitting the mines. Extrapolating from other sites like Hong Kong or Brazil is uncertain. The toxicity of mercury reflects other issues like the concentration of selenium which is known to assist in mercury detoxification (Koeman et al. 1973, Chen et al. 2001). Brazil is known to have naturally high concentrations of selenium which provides some protection from mercury (De Campos et al. 2002). If it were possible to do any clinical analysis of disease and the relationship with mercury, it would be wise to include other measurements of mercury. Mercury in hair is accurate, sensitive and provides a good integration of exposure to mercury. But further insights could be obtained by doing mercury analysis of urine (Adimado and Baah 2002), blood or breath. Any health analysis would be challenged by the lack of local medical resources and more serious issues than mercury. For example in this province, one in four children die before the age of five (National Institute of Statistics 2001).

The isolation of the miners likely contributes to malnutrition. Training and support to establish gardens could be effective. Parasites should be evaluated. Sanitation could likely be improved with donation of latrines. Safety in the mine shafts is a concern.

**Impact on Wildlife**

Earlier one dolphin that had died in the Mekong River was found to have a high concentration of mercury (67 ppm) in its liver. Assessment of rare animals like dolphins is difficult but some monitoring of endangered species is warranted. Several aquatic birds in Cambodia are vulnerable. For example, the rare Pallas's fish eagle (Haliaeetus leucoryphus) can be found at Stung Treng, downstream of the goldmines. Low concentrations of mercury are known to impair development of fish eating birds (Nacci et al. 2005). Fish eating mammals can also be impacted (Aulerich et al. 1974). Monitoring of non-motile animals like the freshwater mussel (Pelecypoda Corbicula Balnddiana or Pelecypoda Corbicula Moreletiana) might be more useful for mapping sources of mercury sources. Monitoring of fish is also important in that they are the major pathway for bioaccumulation of mercury to people and endangered animals. Monitoring of fish is much more difficult in that they move, and their mercury concentration reflects size, and species. There are more than 1000 species of fish.

**Landmine and Unexploded Ordinance (UXO) Contamination**

War records released from the Vietnam War shows areas a few km north of the Prey Meas mine were bombed “exceptionally heavily with munition types more likely to be possibly still dangerous (i.e. Cluster bombs and air-dropped land mines” (Map 6436 Andong Meas). The map indicates a few UXOs were dropped very close to the goldmine. None of miners hesitated to enter the woods and locally deer snares may be more dangerous. NGOs are developing ecotourism along parts of the old Ho Chi Minh trail. Demining is likely required.

**Social concerns**

The migrant workers are paid $70 a month which is about twice the wage for other unskilled workers in Cambodia. However, mine equipment owners have difficulty getting laborers because of the mine has a repudiation for being harsh. The migrant workers spend their money at a local karaoke pub and there are potential impacts on the tribal women in the adjoining village.

The equipment owners are primarily families with many children. There is no school or teacher available at the mine. We did not visit the closest tribal village but a tribal village on the Ou Tran river (Dol, (13°31’51.0” N, 107°26’27.0” E, about 6.1 km east by north) had a school building but no teacher.


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Going up the Tonle Srepok River to Collect Fish Samples


Junction of Ou Tran River and Tonle Srepok River

Potential Hydroelectric Dam Site on Tonle Srepok River, Downstream of Goldmine

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Appendix – more tables will be added as the data is validated
Table 1
Fish collected from Tonle Srepok River Feb.19 and Feb. 20, 2006

| Latin name | FAO name | fish type | weight | Mean Hg | Stdev |
|---|---|---|---|---|---|
| | | | fish g | ng/g | |
| Datnioides quadrifasciatus | barbed tigerfish | fish crustacean predator | 150 | 124 | 5 |
| Clarias meladerma | blackskin catfish | predator | 250 | 84 | 4 |
| Laides sinensis | | unknown | 100 | 52 | 4 |
| Mystus nemurus | | insect, crustacean, fish predator | 200 | 141 | 1 |
| Osphroenmus exodon | elephant ear gourami | herbivore | 400 | 13 | 2 |
| Mystus wykioikes | | not given | 400 | 72 | 4 |
| Pangasius larnaudiei | | fish, insects, plants | 8000 | 112 | 4 |
| Hemisilurus mekongensis | | fish predator | 300 | **206**[2] | 26 |
| Channa marulius | snakehead | fish predator | 1400 | **297**[2] | 15 |
| Channa melasoma | black snakehead | fish predator | 400 | 28 | 4 |
| Channa orientalis | walking snakehead | crustacean fish predator | 50 | 25 | 0 |
| Mystus wykioikes | | crustacean fish predator | 100 | **249**[2] | 16 |
| Microneam micronema | | crustacean fish predator | 100 | **228**[2] | 25 |
| Ompok bimaculatus | butter catfish | crustacean fish predator | 800 | **371**[2] | 29 |
| Channa melasoma | black snakehead | fish predator | 350 | 156 | 3 |
| Channa melasoma | black snakehead | fish predator | 1700 | **414**[2] | 16 |
| Channa melasoma | black snakehead | fish predator | 350 | 60 | 0 |
| Notopteru notopterus | bronze leatherback | insect fish predator | 100 | 53 | 2 |
| Mactrognathus taeniagaster | | insects worms | 100 | 143 | 0 |
| mean<br>Albacore tuna[1] | | | | 149<br>**350**[2] | |

[1] http://www.sciencenews.org/articles/20040327/food.asp
[2] Health Canada (1978, 1984) has recommended mercury not exceed 200 ng/g in subsistence settings where people consume a lot of fish

Table 2

**Total Hg in Dol Village Hair Samples**

Sampled in April, 22,2006

| **Sample ID** | **Age** | **Hg ppb** | **Sex** |
|---|---|---|---|
| Swam | 12 | 1067 | m |
| Viet | 13 | 1263 | m |
| Thien | 15 | 1769 | f |
| Kheng | 25 | 2500 | f |
| Chamlaiw | 26 | 3671 | m |
| Bibng | 30 | 480 | m |
| So Gneon | 35 | 1870 | m |
| Lalair | 40 | 895 | m |
| Kamnot | 18 | 675 | m |
| Mean | | 1577 | |

Table 3

Hair Mine Workers, Prey Meas, Feb. 18, 2006

13°31'22.9" N, 107°22'46.6" E

| Name | Age | Sex | Mean Hg, ppm | St.dev |
|---|---|---|---|---|
| Say Pirum[1] | 21 | m | 687 | 16 |
| Min[1] | 30 | m | 807 | 2 |
| Sat Chek | 30 | m | 3629 | 163 |
| Cheuon[1] | 25 | m | 581 | 26 |
| Se Yatra | 20 | m | 1647 | 31 |
| Thy | 45 | f | 2089 | 132 |
| Rine | 47 | m | 1719 | 30 |
| Sokear | 40 | f | 5044 | 127 |
| Sokha | 25 | m | 2280 | 41 |
| Yo Volarstar | 22 | m | 3288 | 85 |
| Seng Nana | 46 | f | 5315 | 108 |
| Teth Tola | 46 | m | 1260 | 21 |
| Wen Veoung Knan | 39 | m | 1904 | 55 |

[1]These workers only removed rock from the mine shafts.