Community-directed risk assessment of mercury exposure from gold mining in Suriname

Daniel Peplow[1] and Sarah Augustine[2]

Suggested citation Peplow D, Augustine S. Community-directed risk assessment of mercury exposure from gold mining in Suriname. Rev Panam Salud Publica. 2007;22(3):202–10.

ABSTRACT

Objectives. *The overarching objective of this project was to support the indigenous people in Kwakoegron, Suriname, in self-diagnosis of public and environmental health problems. The specific objectives, defined by the people of Kwakoegron were: (1) to determine for themselves if they are at risk of exposure to mercury (Hg) contamination, (2) to measure the extent of the Hg contamination problem, and (3) to initiate an intervention plan.*

Methods. *Field work was conducted from June 2005 to April 2006. Community members were trained to collect hair samples for analysis using methods designed to maximize sample quality and consistency and minimize cross-contamination. Each hair sample, of approximately 20 mg, was weighed, added to the sample boat, and analyzed immediately without preservation or storage. Technicians educated in analytical chemistry and trained in the operation of the portable Lumex Zeeman Hg analyzer measured the total Hg (THg) for each hair sample. Confidential meetings were held with each person sampled and any questions were answered. Afterwards, a community meeting was held to reflect on the process, outcome, and future needs.*

Results. *Hair samples from 16 of the 22 participants had Hg levels of 2.2–20.2 µg/g THg, exceeding normal THg levels for hair (2 µg/g THg). During the confidential, individual meetings and the followup community meeting, information was shared regarding the Hg levels found, what the numbers meant scientifically, what the potential health effects could be, and how exposure levels might be brought down. At the conclusion of the followup meeting, the Kwakoegron community proposed an intervention plan that had three principle parts: (1) routine analysis of Hg exposure to monitor trends and track the effects of exposure-reduction efforts; (2) routine health assessments to determine the effects of Hg exposure, particularly in children less than 5 years of age; and (3) fish advisories based on fish biology and trophic level or on the specific measurement of Hg levels in various fish species from various locations and different times throughout the year.*

Conclusions. *This project showed that a democratic approach to science does not automatically compromise the orderly search for answers. Specifically, our experience in Kwakoegron suggests that the collaborative relationship that emerges by empowering an indigenous community to initiate its own research projects, and address the needs it identifies, can contribute positively to the risk assessment process. This project showed that when Kwakoegron was acknowledged as an equal partner, the risk assessment process led to an open exchange of information and an intervention plan that was both pragmatic and acceptable in the context of the community's unique social and cultural needs.*

Key words Mercury, risk assessment, consumer participation, Suriname.

[1] University of Washington, Seattle, Washington, United States of America (USA). Send correspondence to: Daniel Peplow, 3500 Island Road, White Swan, WA 98952; tel.: 001 509 848-2021; fax: 001 206 543-3254; email: dpeplow@u.washington.edu.

[2] Suriname Indigenous Health Fund, Suriname. White Swan, Washington, USA.

Mercury (Hg) is a well known pollutant of terrestrial and aquatic ecosystems that is damaging human health and the environment around the world (1–3). In Suriname, mercury is still used in gold mining to separate small amounts of gold flakes from large volumes of soil and sediment. Each year, gold mining loses 10–60 tons of Hg in Suriname's interior rainforest (4). Essentially all of the Hg used in gold mining is released into the environment. The affected area extends through more than 50 villages with approximately 50 000 indigenous and tribal residents (10% of the country's total population) (5). These villages are home to five, culturally-distinct groups of Maroons (Ndyuka or Aukaner, Saramaka, Paramaka, Aluku or Boni, Matanai, and Kwinti) and five groups of Amerindians (Wayana, Carib, Arawak, Trio, and Akurio) that live along the rivers in the gold-mining region of eastern Suriname (6, 7). Once released, elemental and inorganic Hg are converted to the highly toxic methylmercury (MeHg) form and bioaccumulate in the aquatic food chain. The Hg exposure pathway that dominates all others on a total Hg (THg) exposure per kilogram (kg) body weight basis is (1):

elemental and/or metallic Hg deposition
↓
soil and water contamination
↓
microbial methylation of elemental Hg
↓
methylmercury uptake in periphyton
↓
methylmercury bioaccumulates in fish
↓
human fish consumption

This pathway is considered to be the primary source of methylmercury to humans in Suriname.

Although numerous risk assessments have been performed, few studies have been published on the effects of Hg pollution on public and environmental health. In the only published study on Hg exposure in Suriname, Mohan et al. (8) analyzed Hg levels in hair samples from 39 mothers and their newborns at the Lands Hospital in Paramaribo. Fourteen (36%) of the mothers and 31 (80%) of the newborns had elevated hair Hg levels. A few reports reveal that the risk disproportionately affects the indigenous and tribal communities (8). Since patterns of fish consumption vary by racial and ethnic group, certain subpopulations may consume contaminated fish more frequently and in greater quantities than others (1). It has been suggested that that the policies and practices that permit the continued use of Hg in gold mining racially discriminate against Maroons and Amerindians who subsist on contaminated fish (8, 9). There are unpublished studies that examined Hg exposure patterns among nonmining communities in Suriname's gold mining areas[3, 4].

While communities such as Kwakoegron are aware of the adverse health effects of Hg exposure and its link to gold mining, the majority remain poorly informed about the precise causes, symptoms, and possible remedies (9). Increasingly, effected communities are suffering from study fatigue. While scientists collect samples and study risk, participating individuals and communities are becoming frustrated because they are not benefiting from the results of these studies. Veiga and Baker (10) note that while biological samples are useful indicators for Hg exposure, in many risk assessment studies, people are seen merely as donors of hair, blood, or urine samples.

In response to studies characterized by a lack of communication between researchers and the study population, various institutions have adopted ethical research guidelines that encourage indigenous and tribal communities to participate (11–13). Typically, new guidelines include checklists, emphasize full disclosure, and require written documentation of consent and support from community leaders and participants. Young (14) said that research is generally conducted in an environment that is not only cross-cultural, but it is also influenced by the relationship between researchers and subjects, and there is often an imbalance of power. Because of this inequity, indigenous peoples are increasingly taking control of their own affairs and are resisting research studies that ignore their community needs and priorities. This situation, combined with our first-hand observation of indigenous communities being marginalized by the research process, led us to propose that a new approach is necessary.

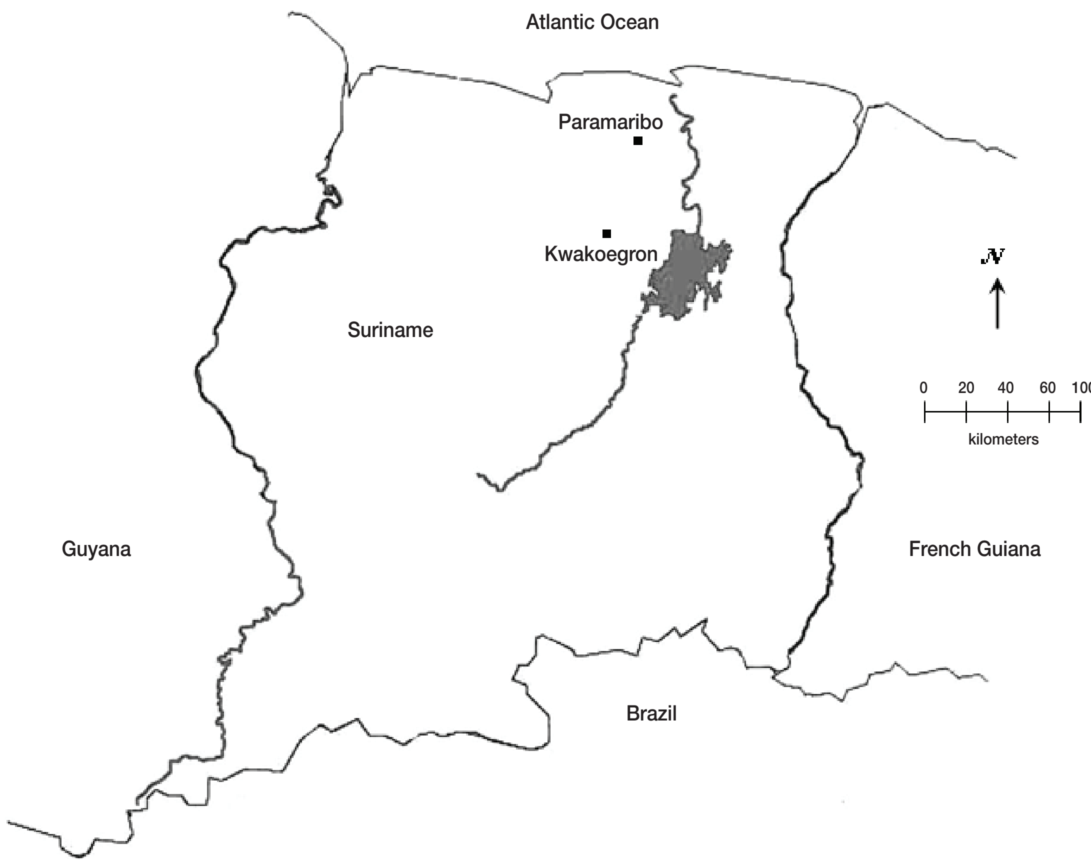
The "Principles for Community-based Research," produced by the University of Washington (Seattle, Washington, United States of America), provides guidelines for socially responsible research and a framework for mutually beneficial relationships between researchers and community members (15). According to these guidelines, there are six principles for Community-Based Research (CBR) that serve as a starting point for defining the relationship between researchers and community members:

(1) Community partners should be involved at the earliest stages of the project, helping to define research objectives and having input into how the project will be organized;
(2) Community partners should have real influence on project direction, that is, enough leverage to ensure that the original goals, mission, and methods of the project are adhered to;
(3) Research processes and outcomes should benefit the community. Community members should be hired and trained whenever possible and appropriate, and the research should help build and enhance community assets;
(4) Community members should be part of the analysis and interpretation of data and should have input into how the results are distrib-

[3] Quik J, Ouboter P. Water quality monitoring in the Commenwijne Watershed, Suriname [A study commissioned by the World Wildlife Fund–Guyana Forests and Environmental Conservation Project]. Paramaribo:Antom de Kom University; 2000.

[4] Pollack H, de Kom J, Quik J, Zuilen L. Introducing retorts for abatement of mercury pollution in Suriname.[Organization of American States Mercury Abatement Project Team Report]. Paramaribo: OAS; 1998.

FIGURE 1. Map of Suriname showing the Kwakoegron study site relative to Paramaribo, the capital city, 2006



uted. This does not imply censorship of data or of publication, but rather, the opportunity to make clear the community's views about the interpretation prior to final publication;

(5) Productive partnerships between researchers and community members should be encouraged to last beyond the life of the project. This will make it more likely that research findings will be incorporated into ongoing community programs, and therefore, provide the greatest possible benefit to the community from research; and,

(6) Community members should be empowered to initiate their own research projects that address needs they identify themselves (15).

The overarching objective of this project was to employ the sixth principle and support the indigenous people in Suriname in self-diagnosis of public and environmental health problems. The assumption was that, if given access to the tools, information, scientific advice, and technical support, an indigenous community would generate its own pragmatic and culturally-appropriate research and intervention strategies. In support of the overarching objective, portable Hg analyzers—recently developed and sold commercially—provided the tools by which an indigenous people in Suriname's interior, might perform real-time testing to determine for themselves the status of their alleged Hg-exposure. Within the overarching objective, the Kwakoegron community defined the objectives of the project itself: to determine for themselves whether they were at risk from exposure to Hg contamination, measure the extent of the Hg contamination problem, and initiate an intervention plan, if needed. The process to accomplish their objectives was to measure and report the Hg levels in their hair and compare those levels to guidelines that indicate risk of adverse effects.

MATERIALS AND METHODS

Context

Suriname is located in northern South America, bordered by the Atlantic Ocean to the north, Guyana to the west, French Guiana to the east, and Brazil to the south (Figure 1). The population of Suriname is 481 146 (2.9 per km^2) (5). Nearly three-quarters of the population lives on the coastal plain that extends inland approximately 30 km; half of the population lives in the capital, Paramaribo (16). The interior is inhabited mainly by indigenous and tribal people. Gold mining, both a source of subsistence for tens of thousands of people and the cause for environmental degradation, occurs mainly in the area inhabited by indigenous and tribal communities (17).

Kwakoegron is located 45 km south of Paramaribo, on the east bank of the Saramacca River near Mindroneti Creek. Kwakoegron is a small village of approximately 25 households. Its inhabitants are Maroon; the descendants of escaped African slaves who established independent societies in the Suriname rainforest in the 17th and 18th centuries. The village features a health clinic operated by Primary Health Care Suriname (a government-sponsored clinic), an elementary school, a telephone center, and local government offices.

The Kwakoegron community was selected because it had requested access to Hg hair-analysis tools and had been part of a previous mercury assessment effort by the United States Embassy in Suriname.[5] Kwakoegron community leaders had also stated that past risk assessments performed by outsiders had not considered the research needs and priorities of the people; as such, they requested assistance with their own risk assessment program.[6] The study protocol was preapproved by the University of Washington Human Subjects Review Board.

Community relations

The people from Kwakoegron work cooperatively within their community, therefore, they requested that scientists and health professionals work cooperatively with their community to develop culturally appropriate Hg intervention programs. Field work took place from June 2005 to April 2006. The initial visit to Kwakoegron focused entirely on defining roles and responsibilities. Kwakoegron identified four commitments that were critical to establishing an effective, cooperative partnership between the scientists/ health professionals and the community:

(1) Self-determination. The participating community was free to participate in, as well as withdraw from the project at any time without reprisal;
(2) Study design. Although we suggested a scientifically-valid plan for collecting samples, the community took into consideration its preferences and needs and decided which sample type would be collected;
(3) Intellectual property. The community was the first to see the final results and these became their intellectual property; and
(4) Data analysis. After the participants saw the results, they were asked in several public meetings to interpret them and draw conclusions from their own perspective.

An anthropologist familiar with the languages and customs of tribal communities in Suriname was employed and instructed in the principles of community-directed risk assessment, and then engaged to observe the study and prepare a narrative describing the activities and conversations. All meetings were conducted in Dutch, the official language of the Surinamese government, or Sranan Tango, the creole language most commonly spoken in the country's interior.

Hg indicator

Generally speaking, biological samples can be used to estimate Hg exposure and bioaccumulation. Possible biological indicators include blood, urine, hair, finger/toe nails, and teeth. Of the five potential indicators considered, four were eliminated for the following reasons: finger/toe nail samples are too often contaminated; teeth samples were not readily available; blood is only an indicator of recent or current Hg exposure, particularly from Hg vapors or high fish ingestion, and its collection is invasive; and urine samples require acidification and additional testing, including the need to correct for creatinine excretion and proteinura. In addition, urine indicates the amount of Hg excreted from the body and is best for recent and intermittent high-intensity inorganic Hg exposure, such as from the elemental Hg vapor produced by amalgam burning.

There were three reasons that hair was determined to be the best bioindicator of long-term exposure to MeHg contamination, particularly from ingestion of Hg-contaminated fish. First, it is the least invasive to collect; second, there are fewer cultural issues involved with collecting it rather than blood or urine; and third, there is less risk of transmitting blood-borne diseases (10).

Based on the rate of hair growth in an individual, the analysis of a 3-cm hair strand provides an average concentration of an individual's diet over the period of time required for the hair to grow that length. Although Hg concentrations can fade slightly over time or can be overestimated if contaminated with Hg that accumulates on the surface from atmospheric sources, the Hg content in a 3-cm hair sample is a useful indicator of Hg exposure. It is not, however, a precise measurement of lifetime exposure nor can it be expected to correspond to blood Hg levels at any particular point in time. Although hair is not as accurate an indicator of Hg vapor exposure as urine is, the community of Kwakoegron was not concerned about elemental Hg-exposure from burning amalgam. They chose hair because it is the best indicator of dietary exposure to MeHg from fish (10).

Three community members received hair-collection training. The training was designed to maximize sample quality and consistency and minimize cross-contamination. The hair collectors wore powderless surgical gloves. Scissors were cleaned with alcohol swabs and dried with kimwipes between samples.

Each hair sample, of approximately 20 mg, was weighed, added to the sample boat, and analyzed immediately without preservation or storage.

[5] Barnes M, Lampron B, Faucher R, Peplow D. Mercury in gold mining operations and its effects on the health of the general population in Suriname (unclassified cable). United States Embassy, Paramaribo, Suriname; 2004.

[6] Peplow D. Failure of science-based policy models to mitigate mercury contamination impacts from gold mines in Suriname. Proceedings of the Fourth Society for Environmental Toxicology and Contamination World Congress. Portland, Oregon, United States of America;14-18 November 2004.

When long hair strands (> 3 cm) were collected, the hair tips were discarded and only the proximal 3 cm were used because MeHg levels can decrease during hair growth under certain conditions, such as treatment with artificial hair-waving (i.e., "perm"). Some difficulties were encountered when attempting to collect samples from men who were either bald or had very short hair. Hair washing procedures were not used to differentiate between airborne and internal Hg.

Analysis of Hg levels in human hair

Group discussions were held to avoid the cultural issues that have become obstacles between scientists and the indigenous communities in the past. In general, active learning methods rather than didactic instruction were used. All the necessary Hg-analysis materials were provided; however, because Hg analysis of biological samples requires advanced skills, technicians educated in analytical chemistry and trained in the operation of the Hg analyzer handled the equipment.

The hair samples were analyzed for THg using the Portable Zeeman Lumex mercury analyzer (model RA915+/RP-91C, Ohio Lumex Co., Twinsburg, Ohio, United States of America). Hg analysis was by the cold-vapor technique. This Hg analyzer is an atomic absorption (AA) spectrophotometer with a 10-m multipath optical cell and Zeeman background correction. Among its features is the direct detection of Hg without preliminary accumulation on a gold trap. The RA915+ includes a built-in zero-mercury supply and test cell for field performance verification. The analyzer was calibrated using NBS traceable standards. The instrument detection level was 0.2 μg/g and the matrix quantitation level was 0.002 μg/g. All concentrations were expressed in parts per million THg (equal to μg/g THg). Measurement of total Hg levels in hair using the Lumex RA915+/RP-91C portable analyzer had been previously confirmed by laboratory analysis using a modified National Institute for Occupational Safety and Health (NIOSH) 6009 method. Regression results showed that Lumex and NIOSH data were comparable (RMS error 0.032, $P < 0.0001$). In this study, the Lumex was operated in software "On Stream" mode using the procedure in the manufacturer's operation manual.

Immediately following the analysis of the hair sample, confidential meetings were held with each person sampled and any questions were answered. Afterwards, a community meeting was held to reflect on the process, outcome, and future needs. The guidelines used to interpret the significance of an individual's results were:

(1) If the laboratory result was less than 1 μg/g, the participant was informed that the Hg level in their hair was below the recommended upper limit of 1 μg/g established by the United States Environmental Protection Agency (EPA) and the National Academy of Sciences (NAS) (1, 18)
(2) If the laboratory result was from 1 μg/g to 11 μg/g, the participant was informed that their Hg level was above the recommended limit and that they could be at elevated risk if pregnant, planning to become pregnant, or nursing a baby. They were advised to seek the advice of a medical professional for any health concerns.
(3) If the laboratory result was greater than 11 μg/g, the participant was told that their Hg level was above the benchmark dose set by the EPA. The benchmark dose for mercury indicates that it is a near certainty that 10% of the births will show neurological defects. They were advised to seek the advice of a medical professional for any health concerns.

RESULTS

Community members in Kwakoegron welcomed the opportunity to learn more about the mercury problem and test the levels of Hg in their hair. The results of the sampling and analysis are given in Table 1. The average level of THg in hair (4.1 ± 4.3 μg/g THg, n = 22) was the same as the levels found in Kwakoegron by another study.[7] Pollack et al. found an average level of 3.8 ± 2.8 μg/g THg in children 0–6 years of age (n = 18) and an average of 4.0 ± 2.2 THg in pregnant women (n = 9).[8] The overall mean value of THg content in Kwakoegron hair samples was 4.1 μg/g, with the highest value being 20.2 μg/g.

TABLE 1. Hair mercury (Hg) concentration in μg/g (μg/g) in 19 female (F) and 3 male (M) residents of Kwakoegron, Suriname, 2006[a]

Age (years)	Gender	Hg
37	M	20.2
3	F	11.7
12	F	6.3
38	F	5.3
38	F	5.0
6	F	4.7
14	F	4.6
60	M	4.3
28	F	3.3
6	F	3.0
4	F	3.0
34	F	2.6
2	F	2.6
42	F	2.4
5	F	2.3
18	F	2.2
60	F	1.6
61	F	1.5
64	M	1.2
29	F	1.2
44	F	1.1
51	F	0.8
Mean		4.1
SD		4.3
Range		0.8–20.2

[a] Hg in hair among unexposed people is 1–2 μg/g hair. The WHO upper limit guideline for pregnant women to prevent damage to the fetus is 10 μg/g hair (29). Research indicates that 5 μg/g hair is the upper limit guideline for pregnant women to prevent damage to the fetus (Veiga et al. 2006). WHO (29) considers for 50 μg/g to be the upper threshold level for paresthesia.

[7] Barnes M, Lampron B, Faucher R, and Peplow D. 2004. Mercury in Gold Mining Operations and its Effects on the Health of the General Population in Suriname (Unclassified Cable). American Embassy, Paramaribo, Suriname.

[8] Pollack H, de Kom J, Quik J, Zuilen L. Introducing retorts for abatement of mercury pollution in Suriname.[Organization of American States (OAS) Mercury Abatement Project Team Report]. Paramaribo: OAS; 1998.

During the confidential data review and the follow-up community meetings, community members recounted that several Hg assessments had taken place prior to this study. One previous assessment had focused on pregnant women. While some results had been shared with the community, the scientists or health care workers conducting these previous studies had not explained what the numbers meant nor were prior assessments part of a longer-term strategy to reduce exposure.

The community self-reported that fish is its main source of protein and it was feared to be the main pathway for Hg exposure. The people tend to eat whatever they catch or may buy fish from neighbors. Some obtain fish from the Brokopondo Lake, which is likely to contain high levels of Hg because it accumulates in this sink from surrounding mines. One alternative, obtaining animal products from the city, is cumbersome and expensive, and bushmeat is sparse.

During the confidential, individual meetings and the followup community meeting, information was shared regarding the Hg levels of the hair samples, what the numbers meant scientifically, what the potential health effects could be, and how exposure levels might be brought down. Comments made during the meetings revealed the Kwakoegron community was committed to developing a strategy for Hg mitigation. At the conclusion of the community meeting, members requested that the Hg analysis team return to assist with a long-term Hg intervention program.

The intervention plan developed by the people of Kwakoegron had three principle parts:

(1) Routine analysis of Hg exposure to monitor trends and track the effects Hg exposure reduction efforts. The community suggested an "Hg Testing Center" be setup, modeled after the Public Health Office's malaria testing center (a laboratory in Paramaribo where individuals can be tested and results are available within a day). Access to an "Hg Testing Center" would help people track their own levels and those of their children, and assist them in evaluating the effects of dietary and behavioral changes. The community would like an Hg analyzer be made available to this proposed center.

(2) Health assessments to determine the effects of Hg exposure, particularly in children less than 5 years of age. Due to the uncertainty of adverse health effects at different levels of Hg exposure as indicated hair, breath, blood, or urine, people generally wanted answers to the question, "What is it [mercury] doing to me and my family?" Because of this, they emphasized that health assessments should focus on minimizing adverse health conditions, particularly in children less than 5 years of age.

(3) Fish advisories based either on fish biology and trophic level or on the specific measurement of Hg levels in various fish species from a variety of locations at different times of the year. Community members wanted to know how to adjust their diets to eating low-risk species of fish.

The community concluded the meeting by drafting a letter to the Suriname Indigenous Health Fund with the following statement and three requests: The community is "tired of scientists studying them," and requests (1) access to Hg self-monitoring resources to detect changes in exposure levels over time, (2) health assessment tests to determine the adverse effects of Hg exposure, especially in their children, and (3) fish advisories so that they may select species that will reduce Hg exposure.

DISCUSSION

Hair samples from 16 of the 22 individuals had Hg levels of 2.2–20.2 μg/g THg, levels which exceed normal THg levels for hair (2 μg/g THg) (18). Another study reported that Hg-levels in hair samples from people of uncontaminated areas of Baghdad, Iraq, were 0.1–4.0 μg/g (19). Baseline levels for Hg in the hair of fish-eating populations in the Amazon River basin and Guiana shield are not available because, even in areas where there are no known inputs, current exposures could have begun with contamination that occurred centuries ago. It is possible that Hg released during the colonial period is now being disbursed throughout the food chain by natural processes. Another potential contribution is contamination by airborne Hg (10, 20, 21).

In Kwakoegron, the highest THg concentration found in hair (20.2 μg/g) surpassed the WHO threshold of 10 μg/g (18) for neurotoxicity in adults and children. The highest concentration in Kwakoegron is equal to the lowest observed effect level (LOEL) of 20 μg/g reported by Label et al. (22) who reported decreased visual acuity (color discrimination loss, contrast sensitivity, and visual field reduction) with increased Hg concentrations in the hair of residents 200 km downstream from gold-mining sites on the Tapajos River in the Amazon. All results were below the threshold (50 μg/g) for parasthesia at the 10% risk level.

In Kwakoegron, total hair Hg in children from 2–12 years of age ranged from 2.3 μg/g to 11.7 μg/g. One child exceeded the benchmark dose estimates for all effects combined (late walking, late talking, mental symptoms, and seizures) corresponding to the 10% extra risk levels (11.1 μg/g) (3). Two children exceeded the lower bound for the 5% risk level (5.4 μg/g) and all seven children exceeded the 1% risk level based on modeling all effects in children.

Although a no observed adverse effect level (NOAEL) does not exist for estimating thresholds for all development endpoints in the developing fetus, data indicate sensitivity 5–10 times that of adults (23). In Minimata, Japan, where consumption of fish with high concentrations of MeHg by pregnant women resulted in at least 30 cases of cerebral palsy in children, exposed women were minimally affected (24). The vulnerability of the developing brain to MeHg reflects the ability of lipophilic MeHg to cross the placenta and concentrate in the central nervous system. Moreover, the blood-brain barrier is not fully developed until after the first year of life, and MeHg crosses this incomplete barrier (25). One complicating factor is that the signs of neurodevelopmental impacts, specifically loss of intelligence, may begin to be manifested several years after exposure when the subclinical effects of mercury toxicity are unmasked by aging (3).

The National Academy of Sciences (NAS, Washington, D.C., United States of America) assessed three, large-scale, prospective epidemiological studies that examined children who were exposed *in utero* to methylmercury. The studies assessed by NAS took place in New Zealand, the Seychelles Islands (Indian Ocean), and the Faroe Islands (North Atlantic). The NAS concluded that the most credible of the three studies was the Faroe Islands investigation, which gave strong evidence indicating that fetal neurotoxicity and delayed brainstem auditory responses occurred at MeHg exposure levels of approximately 1 µg/g Hg in hair (26–29).

As a result of the confidential data review and the follow-up community meetings, it became clear that there is a difference in the way that scientists and the Kwakoegron people view risk. Visiting experts typically see Hg exposure as a science question to be approached in a rational, objective, and value-free manner, while amassing knowledge for its own sake. In contrast, the people of Kwakoegron integrated all technical, social, and cultural factors and used the accumulated data to advocate for a plan to reduce exposure and mitigate adverse health effects. They sought out information that was personally relevant, asking "What will Hg do to me, my family, and my community?" and "How can I reduce its effects?" People potentially exposed to Hg were not passive recipients of information; rather, they adapted the data to meet their needs in the context of their existing beliefs. Communities change when they can plan and own the information over time (30).

The attempt by Pollak et al.[9] to combine assessment and the introduction of retorts to recover Hg from the gold amalgamation process illustrates the problems that occur when there are cultural differences or a history of tension. In Pollak's study, miners did not incorporate the simple, inexpensive technology that would improve their standard gold-processing habits. Henderson et al. (11) attribute failure to a lack of community control, lack of local benefits, and the interpretation of data in isolation from social context.

Real change occurs when experts provide information that is appropriate and allot time for practicing new skills, listening to individual and community concerns, and considering obstacles to success. Failure to affect real change may arise because health professionals are paralyzed by the magnitude of the problem and because vested interests, including those that control development and international health policy, have a stake in observations about causality and are not free to seek real change. Just as data interpreted "out of context" leads to conclusions that lack relevance to scientists, information given to the communities without the opportunity to ask questions leads to efforts that lack relevance to the community.

In the present study, acknowledging the community as an equal partner in the risk assessment process led to an exchange of information and an intervention plan that was both pragmatic and acceptable in the context of the community's unique social and cultural needs. An important factor that contributed to the development of the intervention plan was that community members possessed a basic knowledge of the Hg cycle. They knew, for example, that mercury was acquired from eating fish, and that carnivorous fish (*roofvis*) had higher levels. How Hg had entered the food chain to start with, what mercury could do to people, and how to reduce exposure, were not well understood. It was emphasized to the community that they should not stop eating fish, because excluding this important source of protein from the diet would create other health problems; yet intake of the high-risk species should be limited, especially by young children. The self-diagnosis of Hg bioaccumulation and the potential for adverse health effects from Hg exposure culminated with an intervention plan that detailed three specific needs: (1) access to technology for self-monitoring Hg levels and detecting changes in exposure over time; (2) health assessment tests to determine the adverse effects from Hg exposure, especially in children; and (3) fish advisories that enable people to choose fish species to eat that will reduce exposure.

It became clear to everyone involved that the health concerns related to Hg exposure from gold mining are not being adequately addressed in Suriname. The persistence of Hg in the environment, the pattern of biomagnification as it moves up the food chain, and the extreme toxicity of MeHg on the human nervous system are putting medical, public health, and science professionals under pressure to acquire new knowledge and technology to solve the problem. In developing countries, such as Suriname, however, access to advanced technologies is limited and must be imported. The Portable Zeeman Lumex (RA915$^+$/RP-91C) Hg analyzer is a significant technological development that has made it possible to analyze Hg in hair at remote locations.

So far, intervention programs in Suriname have failed because they have not incorporated the values, research needs, and priorities of the community. Conflicting values and the magnitude of the problem, havemany health professionals feeling paralyzed. In our study, we found the community-driven approach to risk assessment ensured community values were the driving force behind the process of discovery.

[9] Pollack H, de Kom J, Quik J, and Zuilen L. 1998. Introducing Retorts for Abatement of Mercury Pollution in Suriname. Prepared by the Organization of American States (OAS) and HWO Consultants nv, Paramaribo, Suriname.

This project showed that the democratic approach to science does not automatically compromise the orderly search for answers. Specifically, our experience in Kwakoegron suggests that the collaborative relationship that is created when indigenous communities are empowered to initiate their own research projects, and address needs they identify themselves, contributes positively to the risk assessment process. This project showed that when the community of Kwakoegron was acknowledged as an equal partner, the risk assessment process led to an open exchange of information and resulted in an intervention plan that was both pragmatic and acceptable in the context of the community's unique social and cultural needs.

Acknowledgements. This paper reflects the work done at the invitation of the people of Kwakoegron, who, through their collective wisdom, experience, and knowledge, provided the leadership necessary to accomplish this difficult project.

REFERENCES

1. United States Environmental Protection Agency. Mercury study report to Congress. Volume VII: Characterization of human health and wildlife risks from mercury exposure in the United States. Research Triangle Park, NC: EPA; 1997. EPA-452/R-97-009.
2. United Nations Environmental Program. Global Mercury Assessment: Report by the Inter-Organization Programme for the Sound Management of Chemicals. UNEP; 2002.
3. United States Envrionmental Protection Agency. Mercury study report to Congress. Volume V: Health effects of mercury and mercury compounds. Research Triangle Park, NC: EPA; 1997. EPA-452/R-97-007.
4. Gray JE, Labson VF, Weaver JN, and Krabbenhoft DP. Mercury and methylmercury contamination related to artisanal gold mining, Suriname. Geophysical Research Letters. 2002; 29(23):201-4.
5. Algemeen Bureay voor de Statistiek (ABS). 2003 Statistisch Jaarboek. Paramaribo: ABS; 2004.
6. Kambel ER, MacKay F. The Rights of Indigenous Peoples and Maroons in Suriname. Copenhagen: International Working Group for Indigenous Affairs Document No. 96; 1999.
7. Kloos P. The Akuriyo of Surinam: A case of emergence from isolation. Copenhagen: International Working Group for Indigenous Affairs; 1977.
8. Mohan S, Tiller M, van der Voet G, Kanhai H. Mercury exposure of mothers and newborns in Surinam: a pilot study. Clinical Toxicol, 2005;43(2):101–4.
9. Heemskerk M, and Olivieira M. Maroon perceptions of small-scale gold mining impacts: A survey in mining camps and affected communities in Suriname and French Guiana. Available from: http://www.sololiya.fr/content/download/235/1319/version/5/file/Maroon+perception+of+Goldmining-WWF.pdf
10. Veiga MM., Baker RF. Protocols for environmental and health assessment of mercury released by artisanal and small-scale gold miners. Global Mercury Project, Vienna: UNIDO; 2004.
11. Henderson R, Simmons DS, Bourke L, Muir J. Development of guidelines for non-indigenous people undertaking research among the indigenous population of north-east Victoria. Med J Aust. 2002;176(10):482–5.
12. Morgan DL, Allen RJ. Indigenous health: a special moral imperative. Aust NZ J Public Health. 1998;22(6):731–2.
13. Scott K, Receveur O. Ethics for working with communities of indigenous peoples. Can J Physiol Pharmacol. (1995);73(6):751–3.
14. Young TK. Ethical issues in health research among circumpolar indigenous populations. Arctic Med Res. 1995;54(3):114–5.
15. University of Washington. Principles for Community-Based Research. Available from: http://www.washington.edu/research/cbr.html. Accessed 3 June 2007.
16. United States Army Corps of Engineers (US ACE). Water resources assessment of Suriname. Alexandria, VA: US ACE, Mobile District and Topographic Engineering Center; 2001.
17. Nationaal Instituut Voor Milieu en Ontwikkeling in Suriname (NIMOS). Greenstone belt gold mining regional environmental assessment. Paramaribo, Suriname: NIMOS Ministry of Labour Technological Development and Environment; 2003.
18. World Health Organization. Environmental health criteria, 101, methylmercury. Geneva: WHO; 1990.
19. Al-Shahristani H, Al-Hadded IK. Mercury content of hair from normal and poisoned persons. J. Radioanal. Chem. 1973;15:59–70.
20. Malm O. Gold mining as a source of mercury exposure in the Brazilian Amazon. Environmental Research, Section A, 1998;77:73–8.
21. Shrestha KP, Fornerino I. Hair mercury content among residents of Cumana, Venezuela. The Science of the Total Environment, 1987; 63:77–81.
22. Lebel J, Mergler D, Lucotte M, Amorim M, Dolbec J, Miranda D, et. al. Evidence of early nervous system dysfunction in Amazonian populations exposed to low-levels of methylmercury. Neurotoxicology 1996;17(1):157–67.
23. Clarkson TW. Mercury: major issues in environmental health. Environ. Health Perspect. 1992; 10:31–8.
24. Harada Y. Congenital (or fetal) Minamata disease. In: Study Group of Minamata Disease, eds. Minamata Disease. Kumamato, Japan: Kumamato University; 1968. Pp. 93–118.
25. Rodier DC, Schoeny R, Mahaffey K. Methods and rationale for a reference dose for methylmercury by the U.S. EPA. Risk Anal. 2003; 23(1):107–15.
26. Grandjean P, Weihe P, Jorgensen PJ, et al. Impact of maternal seafood diet on fetal exposure to mercury, selenium, and lead. Arch. Environ. Health. 1992;47:185–95.
27. Kjellstrom T, Kennedy P, Wallis S, Mantell C. Physical and mental development of children with prenatal exposure to mercury from fish. Stage I: preliminary tests at age 4 (Report 3080). Solna, Sweden: National Swedish Environmental Protection Board;1986.
28. Kjellstrom T, Kennedy P, Wallis S, Stewart A, Friberg L, Lind B, et al. Physical and mental development of children with prenatal exposure to mercury from fish. Stage II: Interviews and psychological tests at age 6 (Report 3642). Solna, Sweden: National Swedish Environmental Protection Board;1989.
29. Murata K, Weihe P, Budtz-Jorgensen E, Jorgensen PJ, Grandjean P. Delayed brainstem auditory evoked potential latencies in 14-year-old children exposed to methylmercury. J Petiatr 2004; 144(2):177–83.
30. Farmer P. Pathologies of power: Health, human rights, and the new war on the poor. Los Angeles: University of California Press; 2005.

Manuscript received 18 July 2006. Revised version accepted for publication 14 July 2007.

RESUMEN

Evaluación dirigida por la comunidad del riesgo de exposición al mercurio de las minas de oro en Suriname

Objetivos. El objetivo central de este proyecto fue apoyar al pueblo indígena de Kwakoegron, Suriname, a hacer su propio diagnóstico de los problemas de salud pública y ambiental. Los objetivos específicos, definidos por la población de Kwakoegron fueron: 1) determinar por sí mismos si están en riesgo de exposición a la contaminación por mercurio (Hg), 2) medir la magnitud del problema de la contaminación con Hg, y 3) comenzar un plan de intervención.
Métodos. El trabajo de campo se realizó entre junio de 2005 y abril de 2006. Se entrenó a miembros de la comunidad para tomar muestras de pelo para el análisis mediante métodos diseñados para optimizar la calidad y la consistencia de la muestra y minimizar la contaminación cruzada. Cada muestra de pelo, de aproximadamente 20 mg, se pesó, se colocó en el bote de muestras y se analizó inmediatamente sin conservar o almacenar. Un técnico en química analítica entrenado en la operación del analizador portátil de Hg de Lumex Zeeman midió el Hg total (THg) de cada muestra de pelo. Se realizaron conversaciones confidenciales con cada persona muestreada y se respondieron sus dudas. Luego se realizó una reunión con la comunidad para exponer el proceso, los resultados y las necesidades futuras.
Resultados. Las muestras de 16 de los 22 participantes tenían niveles de THg de 2,2-20,2 mg/g, superiores a los niveles normales de THg en pelo (2 mg/g). En las conversaciones confidenciales individuales y en la reunión de seguimiento con la comunidad, se informó sobre los niveles de Hg encontrados, su significado desde el punto de vista científico, los posibles efectos para la salud y cómo se pueden reducir los niveles de exposición. En las conclusiones de la reunión de seguimiento, la comunidad de Kwakoegron propuso un plan de intervención que contaba con tres partes principales: 1) análisis periódicos de la exposición al Hg para monitorear la tendencia y los esfuerzos hechos para reducir la exposición; 2) evaluaciones periódicas del estado de salud para determinar los efectos de la exposición al Hg, particularmente en los niños menores de 5 años de edad; y 3) asesoría pesquera basada en la biología y el nivel trófico o en las mediciones específicas de los niveles de Hg en varias especies de peces de diferentes localidades a lo largo del año.
Conclusiones. Este proyecto demostró que un enfoque democrático en la ciencia no compromete automáticamente la búsqueda ordenada de respuestas. En particular, esta experiencia en Kwakoegron indica que las relaciones de colaboración que surgen al empoderar a una comunidad indígena para que emprenda sus propios proyectos investigativos y responda a las necesidades que ella misma identifica pueden contribuir positivamente al proceso de evaluación de riesgos. Este proyecto demostró que cuando se reconoció a la comunidad de Kwakoegron como socio igualitario, el proceso de evaluación de riesgos llevó a un abierto intercambio de información y a un plan de intervención pragmático y aceptable en el contexto de las necesidades sociales y culturales muy particulares de esta comunidad.

Palabras clave Mercurio, medición de riesgo, participación comunitaria, Suriname.

Cartas / Letters

La Revista Panamericana de Salud Pública/Pan American Journal of Public Health *se complace en publicar cartas de los lectores dirigidas a estimular el diálogo sobre los diversos aspectos de la salud pública en las Américas, así como a esclarecer, discutir o comentar de manera constructiva las ideas expuestas en la revista. Las cartas deben estar firmadas por el autor y especificar su afiliación profesional y dirección postal. Cuando se trate de comentarios sobre un artículo que requieran contestación del autor, se procurará conseguir esa respuesta con el fin de publicar ambas cartas. La Redacción se reserva el derecho de editar las cartas recibidas y resumirlas para mayor claridad.*

The Revista Panamericana de Salud Pública/Pan American Journal of Public Health *publishes letters from readers for the purpose of stimulating dialogue on various aspects of public health in the Americas and of constructively clarifying, discussing, and critiquing the ideas expressed throughout its pages. Letters should be signed by the author and include his or her professional affiliation and mailing address. If a commentary on a given article requires a reply from the author, an effort will be made to obtain the reply and to publish both letters. The editorial team reserves the right to edit all letters received and to condense them so as to improve their clarity.*

COMMUNITY-DIRECTED RISK ASSESSMENT OF MERCURY EXPOSURE: GOLD MINING, FISH, AND UNSUSPECTED ETHYLMERCURY

The interesting paper by Peplow and Augustine (1) addressed an issue important to Amazonian populations: self-diagnosis of environmental and public health problems. The case of the Kwakoegron community of Maroons is particularly interesting because of their awareness of research needs, health priorities, and need for risk assessment programs regarding mercury (Hg) contamination. Based on the research results (and understanding the hair Hg numbers), the villagers "proposed an intervention plan contemplating: (1) routine analysis of Hg exposure to monitor trends and track the effects of exposure-reduction efforts; (2) routine health assessments to determine the effects of Hg exposure, particularly in children less than 5 years of age; and (3) fish advisories based on fish biology and trophic level.…"

I fully agree with the paper's conclusions in the specific confine of their objectives, but I would like to share a broader perspective of issues related to Hg exposure, fish consumption, and alluvial gold mining. For subsistence, fish is a central dietary item of Amazonian villagers (which might be the case with the Kwakoegrons) and, regardless of gold mining activities, they bioconcentrate methylmercury as a secondary constituent (2). The Kwakoegrons' mean hair Hg concentration (4.41 $\mu g \cdot g^{-1}$) denotes regular fish consumption that is much lower than the mean reported for neighboring Rio Negro riverines (3), who are without neurological problems and eat fish from waters with no history of gold mining activity. Although Peplow and Augustine's paper clearly discussed how Hg gets in fish, there is evidence that Hg released from gold amalgamation is only a tiny fraction of the natural Hg in Amazon soil (4). Furthermore, there are no significant differences in mean fish Hg concentration in rivers with and without gold mining activities (5). Actually, the Hg methylation activity (necessary for Hg to gain access to the aquatic food web) explained by Peplow and Augustine is disrupted during river bank dismounting or bottom-sediment scarification (by dredges) commonly applied in alluvial gold extraction in Amazon rivers.

I do not dispute the research findings of neurobehavioral tests in Amazonian fish eaters (the one reporting significant alterations and those showing no effect of fish Hg and not referred to in the paper), but it is important to note that neuropathies associated with food and nutrition in the last two decades have not implicated fish-eating habits (6).

The largest neuropathy outbreak in Cuba was associated with poor nutrition, and endemic TAN (tropical ataxic neuropathy also known as "konzo") is associated with unprocessed cassava cyanogens (6). It should be noted that TAN has never been diagnosed in the Amazon, perhaps because fish provide the necessary sulfur-containing amino acids fundamental in detoxifying excess cyanogens in daily cassava consumption.

Peplow and Augustine covered well the risk involved in Hg exposure during early life, especially the vulnerability of young children (< 1 y of age) when the blood–brain barrier is not fully developed and the complicating factors associated with neurodevelopment are manifested several years after exposure. In this respect, the first line of Hg (ethylmercury) exposure is the use of thimerosal-containing vaccines (7), not direct consumption of fish. Currently, this type of vaccine (because of its low cost) is used only in underdeveloped countries and I suppose that might be the case in Suriname. It will not be long before thimerosal-containing vaccine and early exposure to injected ethylmercury become an issue in Central and South America.

Concerned scientists are interested in the issues discussed by Peplow and Augustine. However, I question whether the complexity involving methylmercury transport in the aquatic food web (and wild fishing choices) and Hg exposure that includes maternal milk of fish-eating mothers and preservatives like thimerosal (used in vaccines) is sufficiently discernible by villagers to distinguish the hazardous forms of Hg (inorganic, fish methylmercury, and injected ethylmercury) exposure and dosage. Instead of concern for environmental issues, we could inadvertently instill alarm about Hg and disrupt subsistence fish eating, breastfeeding, and immunization programs.

José G. Dórea
C.P. 04322
Faculty of Health Sciences
Universidade de Brasilia
70919-970 Brasilia, DF, Brazil
E-mail: dorea@rudah.com.br

References

1. Peplow D, Augustine S. Community-directed risk assessment of mercury exposure from gold mining in Suriname. Rev Panam Salud Publica. 2007;22(3):202–10.
2. Dorea JG. Fish are central in the diet of Amazonian riparians: should we worry about their mercury concentrations? Environ Res. 2003;92(3):232–44.
3. Dorea J, Barbosa AC, Ferrari I, de Souza JR. Mercury in hair and in fish consumed by riparian women of the Rio Negro, Amazon, Brazil. Int J Environ Health Res. 2003;13(3):239–48.
4. Fadini PS, Jardim WF. Is the Negro River Basin (Amazon) impacted by naturally occurring mercury? Sci Total Environ. 2001;275(1–3):71–82.
5. Dórea JG, de Souza JR, Rodrigues P, Ferrari I, Barbosa AC. Hair mercury (signature of fish consumption) and cardiovascular risk in Munduruku and Kayabi Indians of Amazonia. Environ Res. 2005;97(2):209–19.
6. Dórea JG. Cassava cyanogens and fish mercury are high but safely consumed in the diet of native Amazonians. Ecotoxicol Environ Saf. 2004;57(3):248–56.
7. Dórea JG. Exposure to mercury during the first six months via human milk and vaccines: modifying risk factors. Am J Perinatol. 2007;24(7):387–400.

REPLY:

The capacity of scientists to contribute to the resolution of a problem with societal dimensions is negated when highly credentialed and well-respected experts bolster conflicting political and social positions. Dr. Dórea's argument that fish-eating communities in Suriname are not susceptible to the neurobehavioral effects of mercury exposure is an example. On the other side of the argument are equally credentialed and well-respected experts who argue there is no lower threshold to mercury toxicity (1). Grandjean and Kjellstrom and colleagues reported that developmental effects become apparent at levels of approximately one part per million of mercury in hair, or 5.8 µg/L in cord blood (2–4).

The argument that the estimated 30–60 tons of mercury being discharged into the environment each year by mining in Suriname is "only a tiny fraction of the natural mercury that occurs in soil" is another case in point. The release of mercury from natural sources in soil remains about the same over time (5), whereas mercury concentrations in the environment are increasing: this increase is ascribed to mining (6).

Also, the expectation that social or political solutions to a health problem with technical and scientific dimensions can or should be based on scientific consensus is unreasonable. In the case of highly complex and comprehensive social issues, scientific consensus is rarely achieved on an adequate timescale.

The question here is one of "specialized knowledge" when scientists argue that only scientific experts can make wise decisions. The fact is scientific knowledge can only guide, not dictate, societal decisions. It is our opinion that the mercury controversy has little to do with science and everything to do with an ethical and political debate over the allocation of resources, their extraction, and their effects on indigenous communities.

In general, Dr. Dórea argues against involving indigenous people in the resolution of the problem of risk from mercury exposure based on the assertion that the complexity is "not discernible by villagers." Indigenous communities argue that the unique cosmology of forest people, who do not see a clear-cut distinction between the sphere of nature and the sphere of society, is not discernible to Western scientists. Scientists face a huge credibility problem with indigenous peoples because of this position.

This problem is commonly framed entirely in the negative, with indigenous individuals and communities and organizations experiencing scientific research and development as something done by scientists to indigenous peoples. Indigenous leaders no longer want to be the objects of research. The community-driven approach that we described in our paper referenced by Dr. Dórea changes that perspective. It reframes research, development, and the solution to problems as positive. It affirms scientists as experts and indigenous people as equals.

Daniel Peplow
University of Washington
Seattle, WA 98195-2100
E-mail: dpeplow@u.washington.edu
Sarah Augustine
Suriname Indigenous Health Fund
White Swan, WA 98952
E-mail: SIHFund@siihfund.org

References

1. Trasande L, Landrigan PJ, Schechter C. Public health and economic consequences of methyl mercury toxicity to the developing brain. Environ Health Perspect. 2005;113(5):590–6.
2. Grandjean P, Weihe P, White RF, Debes F, Araki S, Yokoyama K, et al. Cognitive deficit in 7-year-old children with prenatal exposure to methylmercury. Neurotoxicol Teratol. 1997;19(6): 417–28.
3. Kjellstrom T, Kennedy P, Wallis S, Mantell C. Physical and mental development of children with prenatal exposure to mercury from fish. Stage I: preliminary tests at age 4. Report 3080. Solna, Sweden: National Swedish Environmental Protection Board; 1986.
4. Kjellstrom T, Kennedy P, Wallis S, Stewart A, Friberg L, Lind B, et al. Physical and mental development of children with prenatal exposure to mercury from fish. Stage II: interviews and psychological tests at age 6. Report 3642. Solna, Sweden: National Swedish Environmental Protection Board; 1989.
5. Langmuir D. Aqueous environmental geochemistry. Upper Saddle River, NJ: Prentice Hall; 1997.
6. Gray JE, Labson VF, Weaver JN, Krabbenhoft DP. Mercury and methylmercury contamination related to artisanal gold mining, Suriname. Geophys Res Lett. 2002;29(23):201–4.