

Fishing activity, health characteristics and mercury exposure of Amerindian women living alongside the Beni River (Amazonian Bolivia)

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Abstract

Populations in Bolivian Amazonia are exposed to mercury contamination through fish ingestion. A group of 170 Amerindian women living along the banks of the Beni River were examined in order to detect any adverse effects on their health consistent with the toxic effects of mercury. The mercury content of the women's hair (H-Hg) was used as the bio-indicator of mercury exposure. The women answered a 24-hour food recall questionnaire on the frequency of their fish consumption. They also underwent a clinical examination with their weight, stature, hemoglobinemia hemoglobin concentration in blood, and blood pressure being recorded. Significant relationships were found between fishing practices, the frequency of fish consumption and H-Hg levels with mercury contaminated women (H-Hg > 5 µg/g) being more likely to present neurological abnormalities (paresthesia, static and dynamic imbalance, poor motor coordination) than non-contaminated women.. No relationship was found between blood pressure and mercury levels. Women with higher H-Hg reported more infant deaths than did women with lower levels. A logistic regression analysis which included socio cultural traits, fish consumption habits and health characteristics was performed in order to determine the risks of contamination. Contaminated women were more likely to belong to those communities pursuing traditional fishing activities; moreover these women tended to be younger and frailer than other. They also exhibited mild neurological abnormalities and reported more infant deaths. These findings should stimulate local communities to take preventive actions directed towards the more "traditional" and vulnerable groups of population.

Keywords: Mercury; neurological outcome; fishing; fish consumption; reproductive health

Introduction

Although mercury contamination through fish ingestion is a threat common to the human populations living in the Amazon Basin (Passos and Mergler, 2008) contamination levels vary greatly from place to place; very high levels have been found in the Negro River, in Amapa State and in some sites of the Madeira and Tapajos River Basins, while much lower levels have been found in the Andean countries of the Upper Amazon (Barbieri and Gardon, 2009). Nevertheless, high levels of mercury have been found in the water, in the sediments and in the fish in the rivers downstream of gold extraction in Bolivia (Maurice-Bourgoin et al., 2000). The source of the contamination was attributed some time ago to the misuse of the mercury used to amalgamate the ore in the mining of alluvial gold (Malm et al., 1995). However gold mining is not the only source of mercury. Tropical soils are mercury-rich, and deforestation, slash-and-burn agriculture or erosion could also bring about the release of this element and thus be another source of contamination (Roulet et al., 1999).

Irrespective of its source, mercury, once released into the rivers, can be converted to methyl mercury (MeHg) by anaerobic bacteria under certain environmental conditions. Methyl-mercury then enters the aquatic organisms and eventually accumulates to reach a maximum concentration at the top of the trophic chain. Fish act as bio-accumulators concentrating and transferring residues from water to humans (Dorea, 2008). Since the banning of the use of MeHg as a fungicide, the ingestion of contaminated fish has become the main route for the exposure of the human population (Clarkson, 1993). This is a cause for concern since fish are irreplaceable food sources for many of the populations in the developing world. Fish are an important source of amino acids and proteins of high nutritional value. Recent research has also stressed their unique role in providing omega 3 fatty acid (Simopoulos, 1991).

There are relatively few studies on the composition of the diet of native Amazonian populations. Manioc (*Manihot esculenta*) and plantain (*Musa paradisiacal*) constitute the staple food but their nutritional value must be enhanced with other foods with high

protein, lipid and mineral contents. Fish, wild game and plants provide the missing nutrients. (Passos and Mergler, 2008, Roche et al., 2007, Sereni Murieta and Dufour, 2004). However, such nutritionally rich foods are widely scattered over the land and the rivers, and their availability is subject to seasonal variation (Passos and Mergler, 2008, Roche et al., 2007). This suggests seasonal food insecurity and emphasizes the importance of fish for the functioning of the Amazonian food system.

After the tragic outbreaks of Minamata (McAlpine and Araki, 1958), culminating in the episode in Iraq in 1971-72 (Bakir et al., 1973), methyl mercury has been recognized as a potent neurotoxin with impacts on the developing brain and responsible for severe neurological dysfunction. Neurological effects are not the only damaging consequences of mercury exposure: cardiovascular abnormalities have also been described. A decrease in heart rate variability was observed in children in the Faroese cohort (Grandjean et al., 2004, Sorensen et al., 1999). Likewise, in Finland, there was a high risk of myocardial infarction later in life which was possibly due to damage to the autonomic nervous system by mercury. (Salonen et al., 1995:38). In addition, epidemiological studies suggest that women's reproductive health could also be harmed by the presence of heavy metals like mercury in water. In the Punjab, a higher risk of still births and abortion was noticed in contaminated areas (Thakur et al., 2010).

In the Upper Amazonian Basin of Bolivia, mercury contamination, resulting from fish ingestion, has been observed in an indigenous population settled along the banks of the Beni River (Maurice-Bourgoinet et al., 2000). However, direct data interpretation among such populations is difficult, since they face many other health threats such as nutritional, parasitic and infectious diseases, which are also harmful to child growth and development (Benefice et al., 2006). Recently a multi-disciplinary study in the flood plains of the Beni River to document mercury contamination of human populations, found that communities continuing to pursue traditional fishing activities were at a higher risk of contamination. (Monrroy et al., 2008). However, the importance of fish consumption in the improvement of children's nutritional status, despite the higher risk of mercury exposure has also been reported (Benefice et al., 2008).

The aim of this study was to further the knowledge gained from previous studies and to provide a more accurate picture of the risk of mercury contamination by identifying the possible links between H-Hg contamination and its effects on the health of a group of Amerindian women.

Methods

Population and setting

The study was performed along the flood plains of the Beni River lying at the foot of the Andes (the Amazon region of Bolivia). Members of fifteen communities living along the banks of the Beni from the Andean foothills to 120 km downstream were visited over a period of 6 months. All women older than 15 (n=173; mean age: 34.9 ± 13.2 years old) who were present during the visit were examined. The sampling details have already been published (Beneficeet al., 2006).

The area is peopled by two Amerindian groups, native from this area, sharing a common origin but with marked differences in their productive activities and cultural traits. The Takanas (148 families) constitute the most important group and are well integrated into Bolivian society; most are able to speak Spanish and to read and write. They are subsistence farmers growing tubers (cassava root), plantains, rice and maize and felling trees for cash incomes. However, they continue to obtain a substantial part of their animal food through hunting and fishing. The second ethnic group, the Esse Ejjas (25 families) engage in fishing as their main subsistence activity. They also grow tubers and rice but in plots smaller than those of the Takanas. Only a few adults of this group had attended school and were able to speak Spanish. In contrast to the Takanas, they represent a more “traditional” Amazonian way of life.

Dietary assessment and fishing practices

Mothers were questioned about their food intake by responding to a 24 hour dietary recall. They were asked to describe each meal eaten at breakfast, lunch, dinner and in-between. They listed the food eaten on the day preceding the survey, and described their cooking practices. The quantities consumed were roughly estimated using common household measures. Data were computed with Nutrisurvey software (release 2007) (<http://www.nutrisurvey.de/>). A database of the food eaten during the survey was elaborated from different sources: the country-specific Nutrisurvey database for Bolivia completed with data from the US. Department of Agriculture (<http://www.nal.usda.gov/fnic/foodcomp/search/>) and the Food and Agriculture

Organization (http://www.fao.org/infoods/tables_latin_en.stm). Nine women did not understand the questions and their responses were not accurate enough to be retained for analysis.

Clinical examination and neurological assessment

All mothers were physically examined by the team physician to determine whether they suffered from any clinically detectable illness. They were asked about toxic habits (smoking and drinking alcohol). Excessive salivation and bluish staining of the gums were also looked for. Women were also asked about their child bearing histories, that is, the numbers of their children, of spontaneous abortions and of stillbirths or infants dying soon after delivery. Unfortunately, in the absence of medical records, it was not possible to get precise information.

All women were systematically examined to detect any of the neurological abnormalities commonly associated with mercury contamination. Responses were scored as “yes” (normal response or absence) or “no” (weak response or presence). The following symptoms were looked for:

- Sensorial domain:
 - Peripheral vision field: The subject was seated in front of the observer and asked to focus on the observer’s nose. The observer begins with his arms outstretched and gradually brought them together. The subject without moving her head was asked to say when the observers’ hands were visible.
- Somato-sensory disturbances
 - Detection of hyper- or hypoesthesia: by rubbing the forearm skin with a smooth brush.
 - Deep sensitivity: by perception of percussion of the pre-tibia area.
 - Discriminative sensory function was explored by exercising light pressure with a needle on two points separated by 5 mm on the finger tip
 - Existence of paresthesia.

- Motricity
 - Involuntary movements: existence of tremor (fingers and tongue).
Existence of rapid eye movements (nystagmus)
 - Static balance, eyes closed.
 - Dynamic balance: instability when walking forwards and backwards along a 3 m straight line with the eyes closed.
 - Upper limb coordination: detection of dysmetria by the finger to nose test. Adiadochokinesis was detected by rapid alternate hand movements of pronation and supination.
 - Tendon reflexes (patellar and Achilles tendons).

Anthropometry, blood pressure assessment and hemoglobin concentration in blood hemoglobinemia

Each woman was weighed on an electronic Seca scale accurate to 100 g; standing height was recorded with a Harpenden anthropometer. The body mass index was calculated as $BMI = (\text{Weight, kg}) / (\text{height, m})^2$.

Blood pressure (BP) measured at the end of the clinical examination, was taken by the same observer throughout the study with the women sitting quietly in armchairs. Two consecutive measurements were taken on the right side. Maximal (systolic) and minimal (diastolic) pressures were recorded in mm Hg using a mechanical manometer and a stethoscope.

Finally, a drop of blood was taken from the mothers by a finger prick for analysis of its hemoglobin content using a HemocueR AB portable spectrophotometer (Ångelhom, Sweden)

Hair mercury content

In this paper, the total hair mercury content (H-Hg) was used as the indicator of mercury contamination through fish consumption (Passos and Mergler, 2008). Hair strands were cut at the occipital region and stored in paper envelopes. Mercury analyses were carried

out in the Laboratory of Environment Quality (LCA) of the Ecology Institute of La Paz University. Hair samples were rinsed in 0.01% ethylene diamine tetraacetic acid (EDTA). Analyses were performed on the whole length of the hair. A 20 mg dry hair sample was digested using acids (two volumes of nitric acid [HNO₃] to one volume of sulfuric acid [H₂SO₄]). Measurements were taken using cold vapor coupled with atomic absorption spectrometry (Perkin Elmer 3110®). All analyses were carried out in duplicate (Maurice-Bourgoinet al., 2000). If these measurements differed by more than 10%, a third analysis was performed. If this was not possible (e.g. insufficient material), the values were discarded. This was the case for 7 women.

Statistics

Biological and clinical data were entered and double-checked using “data compare” software from Epi info (<http://www.cdc.gov/epiinfo>). Indices of the dispersion of variables (standard deviation, median, percentiles) were calculated. H-Hg had a heavy tail towards the right, but after log transformation, the hypothesis of a normal distribution was accepted. Thus, log-transformed values of H-Hg were used in the statistical analysis instead of the crude values in the case of mean comparisons. Non-parametric testing was used for bivariate comparisons. Logistic regression procedures were used to test multiple associations between the presence of significant mercury contamination (H-Hg > 5 µg/g) and a set of independent variables representative of the women’s characteristics. Statistical analyses were performed using NCSS (release 2006) statistical software <http://www.ncss.com>.

Ethics

The study was approved by the Review Board of the SELADIS (Instituto de Servicios de Laboratorio de Diagnostico e Investigacion en Salud, Universidad Mayor de San Andres, La Paz Bolivia) and received ethical clearance from the National Bioethics Committee of Bolivia as well as the Consultative Committee on Deontology and Bioethics of the IRD. The aims of the survey were explained to the community leaders and individually to the families involved. All women signed an informed consent approval form.

Results

Overall the average level of H-Hg in the women was moderate (median 4.4 µg/g, however 14.7% of the women had values greater than 10 µg/g. There were no pregnant women with H-Hg levels greater than 10 µg/g. The Esse Ejjas women presented with H-Hg levels which were significantly higher than those of the Tacanas women (n=148): 10.26 ± 4.19 H-Hg versus 4.65 ± 3.5 H-Hg ($t=7.1$, $p < 0.0001$ respectively).

Dietary habits

161 mothers of the total of 173 completed the food intake questionnaire correctly. Usual meals consisted of gruel, made with a great variety of ingredients (vegetables, maize, fish, chicken or pork) and of a second dish of rice, plátano (*Musa paradisiaca*) or yucca (*Manihot esculenta*) sometimes boiled or fried in lard or margarine. Fish which were never eaten raw were gutted and either fried or grilled. A wide variety of fruit was consumed (banana, avocado, lime, lemon, grapefruit, guava, papaya, carambola, cocoa, and coconut). In communities close to the main provincial town, industrial products (oil, milk and milk-substitutes, cookies, soft drinks and beer) were occasionally purchased. The main dietary energy contribution ($31 \pm 13\%$ of energy) was from cereals (mainly rice), followed by starchy roots (mainly cassava) ($22 \pm 12\%$). However when all the animal products (meat, venison, fish, milk and eggs) were grouped in a single category, these became the second most important energy provider, contributing $24.7 \pm 12.8\%$ (median: 23). The contribution from fruit was noteworthy since not only did fruit provide $10.6 \pm 7\%$ of energy, but it was also the major source of vitamin C (64%) and thiamine (25%) and provided 21% of calcium and 14% of vitamin E. Other items (sweets, legumes, vegetables, beverages) were not regularly consumed and made just a minimal contribution to the energy content of the diet.

Fish eating habits and fishing practices

A total of 33 women (19%) said that they ate fish at least once a day; 106 (61.2%) ate fish at least once a week and 34 (19.6%) ate fish less than once a week. The 24-hour food recall provided additional information with 67 women (41% of the sample) having eaten fish during the day of the survey. Although this fish provided only 4.7% of the overall

energy content in the whole sample, it was the second most important source of protein (21%). For the 67 women who ate fish during the survey, it provided 11% of their energy and 44.6% of their protein needs.

Women correctly identified 18 different varieties of fish eaten on a regular basis. The “sabalo” or *Prochilodus nigricans* was the variety consumed most often (eaten by 43.5% of the sample); second was the pacù (*Colossoma macropenum*) (by 9.1%); third was the “pintado” *Pseudoplatystoma fashiatum* (by 9 %) and fourth was the “palometa” or *Pygocentrus nattereri* (by 6.4%). The sabalo and pacù are herbivorous fish with low mercury contents of 0.078 µg/g wet weight and 0.094 µg/g wet weight respectively (Maurice-Bourgoinet al., 2000). Both the pintado, a piscivorous fish and the palometa, a carnivorous fish, had higher mercury contents of 0.43 µg/g wet weight and 1.22 µg/g wet weight respectively (Maurice-Bourgoinet al., 2000).

Table 1 presents the significant relationships existing between fishing, fish consumption the frequency of consumption and H-Hg levels. Women from families who continued to pursue more traditional and substantial fishing activities and who consumed fish on a daily basis presented with higher H-Hg levels

Health characteristics

Of the 173 women examined, six spontaneously reported that they experienced periodic violent headaches (similar to migraines); one occasionally had involuntary muscle contractions during sleep (myoclonic movements); one presented a clear intellectual deficit and was unable to learn at school. None reported excessive salivation or presented bluish coloration of the gums. Twenty-six women (15%) smoked from time to time (less than 3 cigarettes per day) and eight (4.6%) reported drinking alcohol at least once a week.

The physical characteristics of the women studied are shown in Table 2. A relatively high percentage of the women (21.3%) were of short stature; and more than 40% were overweight. The prevalence of anemia was also high (22.3%). When women were divided in two groups (contaminated: H-Hg > 5 µg/g) and non-contaminated (H-Hg ≤ 5

µg/g), there were no group differences in terms of age, BMI, stature or blood hemoglobin.

On average, blood pressure (BP) was low (systolic BP: 106.9 ± 14.8 mm Hg, median= 108 mm Hg; diastolic BP: 66.2 ± 9.3 , median = 65 mm Hg). The maximum value recorded was 170 mm Hg. Only seven women had systolic BP over 130 mm Hg. None had diastolic BP over 90 mm Hg. No correlation between BP and H-Hg levels was found. Multiple regression analysis, with systolic BP as the dependent variable and age, BMI, H-Hg, H-Hb (numeric) and ethnic group (categorical) as independent variables, was performed. The regression performed well and provided a high coefficient of determination ($R^2=0.27$, $F < 0.0001$). Only age and BMI were significant predictors of BP ($r_{\text{age}}=0.21$, $p<0.001$; $r_{\text{BMI}}= 0.6$, $p<0.005$).

Neurological evaluation

Not all women were able to perform the neurological tests correctly: about 9% failed depending on the test. Overall, a relatively small percentage of women presented abnormal responses. These included the reduction of the visual field (14%); the presence of paresthesia (12%); disturbances in balance (31%); and disturbances in motor coordination (dysmetria and adiadochokinesis) (14%). There were no cases of tremor (hand or tongue) or of nystagmus. Abnormal responses occurred in at least 5% of the women in the sample. A comparison was made of the occurrence of such abnormal responses in women with H-Hg levels below or above 5 µg/g. The results are shown in Table 3. On two occasions (the presence of paresthesia and disturbance of static balance) abnormalities occurred more often in contaminated women. No associations between these abnormalities and smoking or drinking habits were found.

Reproductive health

Overall, the women had an average of five living children and had experienced one infant death. Twenty percent of women were not menstruating and were considered as being post-menopausal. There were no differences in their H-Hg levels compared to the levels of reproductively active women (Table 3). H-Hg levels were lower in pregnant women

than in those who were not pregnant but this was the reverse in lactating women who had higher H-Hg levels than did non-lactating women. Women who had lost children presented higher H-Hg levels than those who had not. No relationship was found between the H-Hg levels and the number of abortions.

Characterization of H-Hg contaminated women

Since many of the variables found to be associated with mercury contamination, are inter-related in order to eliminate any redundancies and to attempt to draw a profile of the risk of mercury contamination, a logistic regression was run. Mercury contamination was used as the dependent variable (contamination: H-Hg > 5 µg/g; no contamination, H-Hg ≤ 5 µg/g). Fish consumption and fishing practices, ethnicity, neurological abnormalities, blood hemoglobin, BMI, age, and child death were used as the possible causative variables. The results are presented in Table 4. Logistic regression model was successfully performed and correctly classified 74 % of the subjects. Contaminated women for the most part were young, with a low BMI and were likely to present paresthesia and balance disturbance. They reported infant deaths. They ate fish frequently and tended to belong to the Esse Ejjas ethnic group. A livelihood style unrelated to fishing had a protective effect. Blood hemoglobin was not associated with levels of mercury contamination.

Discussion

This paper investigates the clinical status of a group of women living along the banks of the Beni River. Statistically significant relationships were found between fishing activity, fish consumption, certain physical and neurological abnormalities of these women and their hair mercury content. There was no association between mercury exposure and blood pressure.

Some weaknesses of the study need to be addressed. The neurological examination consisted of clinical observations of symptoms and of the behavior of individuals with no elaborate testing being performed. Scoring (the presence or absence of abnormalities) was kept simple in order to avoid errors, and thus the interpretation could not be fine-tuned. The cross-sectional design of the study did not enable demonstration of a cause-and-effect relationship between the presence of abnormalities and that of mercury. Despite these limitations, the findings are consistent with a mild to moderate clinical impact of mercury exposure in that community. The strength of this study lies in the fact that it included free-living populations who did not professionally handle mercury.

Fish consumption is the main route of mercury contamination in populations (Clarkson, 1993, Mergler et al., 2007). However in this study, fish consumption was moderate: less than 20% of the women ate fish every day and only 41% had consumed a fish meal during the day of survey. The quantity eaten provided only 11% of their energy requirements. This is a cause for concern, since the bulk of the diet, consisting of cassava and plantain, of this population, is unable to satisfy normal nutritional requirements. In this context, the fish intake represents a highly nutritious food for many riverside families. This dual role of fish, a nutritionally desirable food but also the route for mercury contamination, represents a real public health challenge. In addition, some frequently eaten foods, such as fruit, can affect the absorption or excretion of Me-Hg. In communities living along the Tapajos River (in Brazil), individuals who often ate fruit had lower H-Hg levels than did others (Passos et al., 2007). Indeed, in this study, 90% of the women reported eating fruit regularly. Fruit was the third most energy source in their diet and provided important micronutrients. A protective effect of fruit against mercury

contamination, via phytochemicals able to interact with the absorption, excretion and transport of toxic metals, has been postulated (Peraza et al., 1998). Fruit supplies vitamins C and E that possess anti-oxidant properties and may neutralize the toxic effects of mercury (Jacob-Ferreira et al., 2009).

The neurological abnormalities detected in our study, i.e. visual field constriction, balance dysfunction, motor coordination anomalies and paresthesia, were compatible with the effects of mercury brain-damage to areas such as the visual cortex and the granular cerebellum layer (WHO, 1990). However these abnormalities are not specific to mercury intoxication and are observed in other situations. For instance, it is known that iron is involved in numerous biochemical pathways influencing brain function and myelin production (Todorich et al., 2009). Similarly, aging (Fjell et al., 2009), malnutrition and deprived cultural and environmental conditions can lead to neurological dysfunction (Alvarez, 1982). Studies performed in Amazonian adults lend support to our findings. In 1996, in the Rio Tapajos, Lebel and coworkers observed that at H-Hg levels below 50 µg/g, visual disturbances and neuro-physiological changes were observed (Lebel et al., 1996). In a fishing community of Mato Grosso (in Brazil), with H-Hg levels varying from 0.56 to 13.6 µg/g, dysfunctions in fine motor performance as well as in verbal learning and memory were detected. There existed a dose-response relationship effect with mercury (Yokoo et al., 2003). Similarly, along the Tapajos River, a group of adult fishermen with high H-Hg concentrations (14.1-20.8 ppm) presented sensitivity troubles compatible with mild Minamata disease (Harada et al., 2001). Contrary to these reports, Dorea did not find any neurological symptoms in adult women with H-Hg levels ranging from 6 to 32 µg/g (Dorea et al., 2003).

Mercury is blamed for producing elevated blood pressure, possibly through an alteration of the autonomous nervous system. A study from Tapajos found a 3-times-greater risk of having high BP (greater than 130 mm Hg) when the H-Hg content was more than 10 µg/g. Such a relationship was not found in Amerindian tribes of Eastern Amazonia. On the contrary, there was a trend of lower BP in fish consumers (Dorea et al., 2005). In this

study, as a rule, women presented low blood pressures and there were no relationships with their H-Hg levels.

After the Minamata disaster in Japan, the existence of reproductive outcomes linked to environmental hazards rather than to occupational hazards, was suspected. Surveys reported an increase in abnormal conception (stillbirths and abortions) after the 1960s with a peak between 1965 and 1970 (Inaoka and Nagano, 1995). This suggests a long term effect of methyl mercury on the reproductive status of young women exposed during their childhood. A recent retrospective study performed in two heavily contaminated areas of Japan comparing a non-exposed area with an exposed area, demonstrated an increase in abnormal pregnancies during the period of severe mercury contamination (Itai et al., 2004). As stated already, no causative association was found in this study between H-Hg levels and infant deaths after delivery. However, detailed information on the circumstances of the deaths were not available and in many cases women gave birth alone at home. Such circumstances pose, per se, a threat during delivery. It is nonetheless disturbing that there was a greater probability of infant deaths in women in the contaminated group, after taking into account other factors.

The fact that pregnant women presented lower H-Hg levels than non pregnant women is reassuring because of the capacity of methyl mercury to cross both the placenta and the brain barrier and to impair the cerebral development of infants (Gilbert and Grant-Webster, 1995). However the reverse relationship in lactating mothers is worrying. Mercury exists in human milk in proportion to that in maternal blood although at a lower concentration. In the past, studies advised against breast feeding for a long period in fishing communities (Grandjean et al., 1994). At present, the benefits of breast feeding in terms of the neurodevelopment of children living in stressful environments are generally considered to outweigh the risks of mercury poisoning (Jensen et al., 2005, Marques et al., 2009). However, in this study, women breast-fed their children for a long time (mean age of weaning: 16.8 ± 6.5 months (Benefice et al., 2006)), and could be an issue.

The inconsistency and unpredictability of outcomes could be due to the variability in fish mercury content concomitant with its protective effect. A recent review of mercury contamination in the Amazonian countries outlined the complexity of the situation due to the multiplicity of sources (anthropogenic or not) and factors which may reduce exposure (such as fruit consumption, intake of selenium) or increase exposure (such as the methylation process) (Passos and Mergler, 2008). These factors, in turn, are affected by individual, genetic, cultural and public health issues. Certain researchers, when confronted with these multiple challenges, propose an ecosystem approach in order to better understand the situation and establish priorities (Webb, 2005). Indigenous communities and women in particular, because of their central role in family nutrition and health, are the first victims and thus play a pivotal role in prevention. They should therefore participate in the process of finding appropriate and acceptable solutions (Passos et al., 2007). In Bolivia, progress has been made in identifying the risks to human populations of mercury exposure (Barbieri et al., 2009, Maurice-Bourgoinet et al., 2000, Monroyet et al., 2008), but key data on fish contamination are lacking, and until now, we cannot fully understand the magnitude of the process and the risks to human beings.

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