Biological Monitoring for Mercury within a Community with Soil and Fish Contamination

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To assess the impact of elevated levels of inorganic mercury in soil and dust and organic mercury in fish, biological monitoring was conducted among Native Americans living next to an inactive mercury mine in Clear Lake, California. Of resident tribal members, 46% ($n = 56$) participated in biomonitoring. Urine mercury levels are equivalent to background, indicating that soil and dust exposures among study participants are not substantial. The average blood organic mercury level among study participants is 15.6 ± 8.8 µg/l ($n = 44$), which is higher than levels reported by others among those who do not consume fish (2 µg/l). Consistent with results from other studies, a correlation between fish consumption and blood organic mercury is observed ($p = 0.03$). The margin between observed and established adverse effect levels for adults is examined for blood organic mercury and found to be less than 10-fold for 20% of the study population. Protective public health efforts for the study population and other similarly exposed populations, notably those who consume commercial fish products, are considered. *Key words*: contaminated soil, fish advisories, fish consumption, inorganic mercury, methyl mercury, Native Americans. *Environ Health Perspect* 105:424–429 (1997)

Large regions of North America, including the Northern California coastal mountains, are rich in inorganic mercury ores, particularly cinnabar (HgS) (*1*). Elevated environmental concentrations of mercury occur in these regions (*2*). Inorganic mercury vapor (Hg^0) is readily absorbed and neurotoxic (*3*). Human uptake of cinnabar, however, has not been studied.

Environmental mechanisms transform inorganic mercury to organic mercury. Organic mercury accumulates in the food chain, is efficiently absorbed, crosses the blood–brain and placenta barriers, and is neurotoxic and teratogenic (*3*). These effects were recognized in the 1960s when consumption of contaminated fish in Minamata, Japan, resulted in neurological effects, including cerebral palsy and death (*4,5*). Fish mercury concentrations associated with disease in Japan, 3–30 µg/g (*5*), were about 100-fold greater than the current average concentration in U.S. fish products, 0.1 µg/g (*6*). In the United States, approximately 840 sport-fish consumption advisories exist due to mercury contamination (*6*), and the U.S. Food and Drug Administration (FDA) advises that pregnant women limit consumption of top predators, e.g., swordfish, to less than once a month (*7*).

Biological monitoring can assess organic and inorganic exposures. Fish consumption is the dominant source of organic mercury. Organic mercury in blood reflects current exposures (half-life is 36–160 days); hair reflects recent and historical exposures, each centimeter representing approximately a month of exposure (*3*). Organic mercury is minimally (4% of dose) excreted in urine (*8*). In contrast, inorganic mercury is predominately excreted through urine and feces. Hence, mercury in urine primarily represents inorganic sources. Inorganic sources include not only soil and dust but also mercury vapor exposures from sources such as smelting, dental amalgams, and occupational exposures. Mercury in urine has a 60-day half-life. Inorganic mercury can also be measured in blood, but this is less frequently conducted (*3*).

Within a Native American community, the California Department of Health Services (CDHS) conducted biological monitoring to assess exposures to elevated mercury concentrations in soil and fish. Results also allowed the CDHS to consider protective public health actions within the study population and other similarly exposed populations.

Site History

The Sulphur Bank Mercury Mine (SBMM) is located in the Northern California coastal mountains on Clear Lake, a recreational resource, 75 miles north of the San Francisco-Oakland Bay Area. Between 1870 and 1957, cinnabar was mined at the SBMM. Today, 1.7 million cubic yards of waste rock are on the site. A Native American Tribal Rancheria and a few other homes are adjacent to the SBMM.

Rancheria soil averages 50 µg Hg/g (*9*), 100-fold above background (*1*). Drinking and lake water mercury concentrations and ambient air mercury vapor concentrations are not significantly elevated. Total mercury in air has not been measured (*9*).

Among fish in Clear Lake, 8–18% of the top predators exceed 1 µg Hg/g, the federal action level (*10,11*). In 1987, the CDHS established a consumption advisory for lake fish in Northern California. For nonpregnant adults, guidelines were established by dividing species-specific consumption rates necessary to achieve potential adverse effect blood levels by a safety factor of 10 (Table 1) (*10,12*). This procedure establishes a maximum tolerable daily intake of 30 µg organic mercury for nonpregnant adults, the same as that used by the FDA. The FDA, however, issues no advisories for nonpregnant adults for similar levels of contamination in commercial fish because of estimates that average U.S. fish consumers have mercury intake from consumption of commercial fish within the tolerable intake (*11*). The CDHS also advised pregnant and nursing women and children less than 5 years old not to eat fish from Northern California lakes based on plausible greater sensitivity and additive mercury intake from commercial fish (*10*). There are no posted warnings at Northern California lakes; however, the consumption guidelines are distributed at fish licensing locations (*13*). In early 1992, meetings with Rancheria community leaders indicated a general awareness of the fishing advisory.

Potential exposures to mercury in soil and dust, and potential subsistence fishing, warranted biological sampling among the Rancheria community. In 1992, remediation activities considerably elevated community interest. This awareness led to immediate initiation of biological sampling when federal funds became available in October 1992. Temperatures also continued to be warm, which represented a likelihood of continued summer-related outdoor activities.

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Methods

Evaluation levels. For urine mercury and blood organic mercury, background, elevated, and benchmark adverse effect levels (*3–5,14–16*) and the protective public health actions warranted by these levels were established *a priori*. The community was informed that at elevated levels, repeat testing and counseling to reduce exposures would be warranted; at adverse effect levels, medical referrals and removal from exposure would also be warranted.

Sample collection. The 123 members listed on tribe scrolls as Rancheria residents and the residents of five adjacent homes were targeted. Approval of the California Health and Welfare Committee for the protection of human subjects was obtained.

Residents were visited twice prior to testing, during which time the reasons for the testing and the fishing advisory were reviewed. A fact sheet describing the testing was distributed. Residents were asked to go to the Rancheria community room in mid-November 1992. Trained interviewers obtained informed consent and administered a questionnaire. To ensure participation, the questionnaire was brief. Questions included activities related to potential SBMM exposure, e.g., walking on SBMM, and other possible mercury exposures, e.g., occupation and use of over-the-counter products, such as skin-lightening creams (*17*). For sport and commercial fish consumption, respondents were asked what type of fish they had consumed over the past 6 months, the estimated average number of times per week they ate the fish, and the average amount (in pounds) they ate at each meal. Fish models were not obtained in time for sample collection and were not used. Children under 10 years of age were interviewed with their parents.

Spot urine samples were collected. Blood was collected by venipuncture into 7 ml heparinized vacutainers previously determined to be free of mercury. Approximately 40–100 strands of hair were clamped and clipped next to the scalp.

Analytical. Samples were prepared for analysis of total mercury by adding sulfuric and nitric acids, potassium permanganate, and potassium persulfate and heating to break down organomercury compounds and oxidize the released mercury to Hg^{2+} in solution. Hyroxylamine hydrochloride or hydroxylamine sulfate was added to reduce excess oxidant in the digested samples (*18*). Replicate blood and hair samples were prepared for analysis of inorganic mercury by adding sodium or potassium hydroxide to break down the sample matrix (*19*). L-cysteine was added to retain mercury in solution (*20*). Specific reagent concentrations and digestion conditions were matrix dependent.

Quantitation of mercury in sample extracts was by continuous flow cold vapor atomic absorption spectroscopy using stannous chloride as the reductant (*18–21*). Organic mercury in blood and hair was taken as the difference between total and inorganic mercury. Urine creatinine was determined colorimetrically (*22*). Hair samples were rinsed with ASTM Type II water (ASTM, Philadelphia, PA) and acetone, and the centimeter closest to the scalp was analyzed.

Quality control samples were run every 6–10 analyses. Analytical method blanks were all below detection limits. Recoveries of spiked samples ranged between 80 and 113%. Analyses of reference materials were within 99–130, 84–116, and 97–105% of target values for urine, blood, and hair values, respectively. For urine, National Institute of Standards and Technology (Gaithersburg, MD) Standard Reference Material 2672 was used. For blood, standards were obtained from the Center de Toxicologic due Quebec (Quebec, Canada). For hair, samples were obtained from the Mercury Quality Control Program (Occupational Health Sciences, Health and Welfare, Ottawa, Canada).

The distributions of measurements were tested for normality via the W-statistic and log-transformed when appropriate. Regression analysis and *t*-tests were used to test for individual associations between questionnaire variables and biological levels. Multiple regression analysis was used to test independent variables in combination (*23*).

Results

Participation. Sixty-three tribal members participated in biological monitoring; 26 under 18 years old. Fifty-six were residents and represented 46% of the resident tribal population. The seven nonresident tribal participants spent an average of 19 hr/week on the Rancheria. Additionally, five of six adults from other homes adjacent to the SBMM participated. Participants expressed concern that blood and hair collection procedures respect cultural traditions and that results be compared to Native American reference populations. Some expressed a lack of interest in being advised on lifestyle activities but did request that the CDHS advise on remediation activities. Some cited other more compelling issues, primarily problems associated with poverty.

Inorganic mercury. Mean mercury urine levels among tribal participants were 1.7 µg/l urine and 1.3 µg/g creatinine (Table 2). Average urine levels fall within levels reported for children of nonoccupationally exposed adults (<5 µg/l) (*24*) and all participant levels are well below the 95th percentile of nonexposed individuals (20 µg/l) (*3*). The mean blood inorganic mer-

Table 1. Mercury levels in Northern California and commercial fish and Northern California lake fish consumption advisory

			Nonpregnant adults	
Source	Species	Average mercury concentration µg/gram (*n*)[a]	Estimated consumption (lb/day)[b] necessary to achieve a blood level of clinical significance[c]	Northern Californian lake fish consumption advisory (lb/month)[d]
Clear Lake, CA: near mine site	Largemouth bass	0.82 (24)	0.8	1–2
Clear Lake, CA	Largemouth bass	0.45 (115)	1.5	1–2
Clear Lake, CA	Channel catfish	0.41 (28)	1.6	1–2
Clear Lake, CA	Crappie	0.38 (51)	1.7	1–3
Clear Lake, CA	White catfish	0.53 (26)	1.2	1–3
Clear Lake, CA	Brown bullhead	0.25 (26)	2.6	6
Clear Lake, CA	Blackfish	0.25 (20)	2.6	6
Clear Lake, CA	Hitch	0.15 (21)	4.4	10
Lake Berryessa, CA	Largemouth bass	0.32 (51)	2.1	1–2
Lake Berryessa, CA	Rainbow trout	0.17 (29)	3.9	10
Lake Herman, CA	Largemouth bass	0.92 (10)	0.7	1
Commercial fish, U.S.	Swordfish	0.95	0.7	No restrictions
Commercial fish, U.S.	Tuna	0.16	4.1	No restrictions
Commercial fish, U.S.	All fin fish	0.11	6.0	No restrictions

n, number.

[a] Data from Committee on Evaluation of the Safety of Fishery Products (*6*) and California Deptment of Health Services (*10*).

[b] Ingestion estimates based on equation: µg Hg/l blood = 0.67 × (µg Hg ingested/day), for a 70 kg person (*12*).

[c] At 200 µg/l, there is increased risk of paresthesia among adults (*4*).

[d] Pregnant or nursing women and children less than 5 years old are advised not to eat any fish from Northern California lakes. Children ages 6–15 are recommended to eat half the amount indicated. When a range is listed, the recommended amount is dependent on the size of the fish caught. Amounts cannot be combined. Data from California Department of Health Services (*10*).

Table 2. Biological mercury levels among participants

Participants	n[a]	Mean	Minimum	Maximum	SD
Urine mercury, unadjusted for creatinine (µg/l urine)					
Tribal members	51	1.7	0.4	12.5	2.0
Others	5	0.7	0.2	2.4	1.0
Urine mercury, adjusted for creatinine (µg/g creatinine)					
Tribal members	49	1.3	0.4	6.1	1.0
Others	5	1.3	0.2	3.0	1.2
Blood inorganic mercury (µg inorganic mercury/l blood)					
Tribal members	44	2.9	0.7	4.7	1.0
Others	4	2.7	1.7	3.4	0.8
Blood organic mercury (µg organic mercury/l blood)					
Tribal members	44	15.6	3.3	38.8	6.6
Others	4	8.8	2.5	12.2	6.9
Hair mercury (µg mercury/g hair—first cm closest to scalp)[b]					
Tribal members	63	0.64	0.3	1.8	0.43
Others	4	1.6	0.3	2.3	0.88

Abbreviations: *n*, number; SD, standard deviation.

[a] Not all participants participated in collection of each biological media. Two participants provided insufficient urine for creatinine determination.

[b] Values less than the detection limit (0.3–0.6 µg/g hair) taken as the detection limit.

Table 3. Fish consumption rates among participant fish consumers over 6 months prior to testing

Clear Lake fish	Average consumption (g/day) among consumers (*n*)	Commercial fish	Average consumption (g/day) among consumers (*n*)
Total Clear Lake fish	60 (23)	Total commercial fish	24 (32)
Fish species		Frequently consumed fish	
Catfish	53 (19)	Tuna	9 (15)
Hitch	12 (4)	Salmon	9 (12)
Perch	74 (4)	Crab	9 (8)
Bass	5 (2)	Snapper	10 (5)
Carp	1 (1)	Shrimp	6 (5)

n, number.

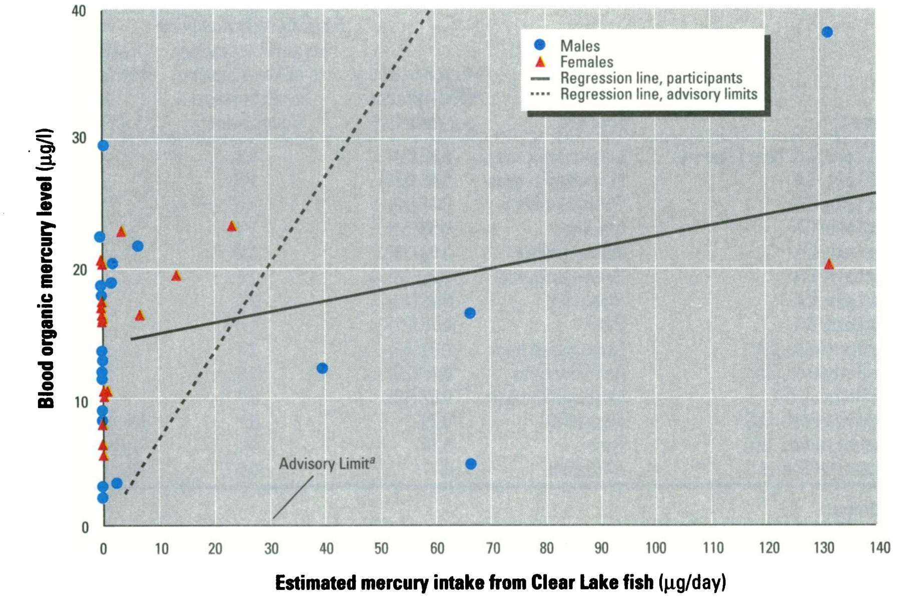

Figure 1. Mercury intake from Clear Lake fish consumption versus blood organic mercury level among participants. The regression line among participants is $a = 14.2$, $b = 0.08$. The regression line used to establish consumption advisory from long-term consumption study is $a = 0$, $b = 0.67$. Data from Kershaw et al. (*12*).
[a] Clear Lake fish consumption guidelines set to limit intake to 30 µg/day.

cury level is 2.9 µg/l, slightly higher than averages in a nonexposed population (1.9 µg/l or less) (*25*).

SBMM-related exposures—i.e., walking/playing on the SBMM, time spent at the Rancheria, child playing outside, contact with lake mud, etc.—are not individually associated with urine mercury or blood inorganic mercury. A multiple linear regression model with these variables and age, gender, fish consumption, and potential mercury exposures external to the SBMM—i.e., occupation, amalgams, etc.—shows a significant relationship only between creatinine-adjusted urine mercury and gender. For these analyses, urine results were log-transformed. The geometric means for females and males were 1.65 and 0.82 µg/g creatinine ($p = 0.02$).

Organic mercury. The mean blood organic mercury level among tribal participants is 15.6 µg/l (Table 2). Nine (20%), including four women of childbearing age, had values above 20 µg/l, the upper end of background (*4*). No pregnant women or children less than 5 years old participated in blood testing.

Reported fish consumption among participants is displayed in Table 3. Most study participants who consumed Clear Lake fish ate catfish; only two ate the territorial bass. Intake of mercury from Clear Lake fish (micrograms of Hg per day) was estimated from reported fish consumption (pounds per week per species) and fish mercury concentration (Table 1). For six adults (10% of all participants) this reported intake exceeded 30 µg/day, the tolerable intake guideline for the Clear Lake advisory (*10,11*). Among those who did not consume Clear Lake fish, the mean organic mercury level was 13.0 µg/l ($n = 27$) and the mean among those exceeding the advisory intake was 18.1 µg/l ($n = 5$). Regression results (adjusted R^2) indicate that mercury intake from Clear Lake fish is a predictor of blood organic mercury level that is not improved by adding age, gender, commercial fish, specific fish species, or other combinations of variables. The univariate regression is statistically significantly ($p = 0.03$), albeit the correlation is weak ($R^2 = 0.1$) (Fig. 1).

Mean total mercury concentrations in first-centimeter hair samples, which correspond to the prior month of exposure, are given in Table 2. Sixty-eight percent, however, were below the detection limit (0.3–0.6 µg Hg/g hair).

Followup testing. In August 1993, participants whose blood organic mercury levels were above 18 µg/l ($n = 15$) were offered repeat testing. Most, however, declined. Repeat values, for the two who participated, were below 10 µg/l.

To follow up on the low hair values obtained among women of child-bearing age (n = 16), two additional segments of hair were analyzed: hair 1–4 cm and 4–7 cm from the scalp. All samples were comparable to the first segment hair values, with a mean of 0.43 µg Hg/g hair, a maximum of 0.9 µg/g hair, and 67% less than the detection limit of 0.3–0.4 µg Hg/g hair.

Discussion

Inorganic mercury. The low background urine levels among participants and the absence of an association of biological levels with possible SBMM exposures indicate that participants' exposures to inorganic mercury in dust and soil were not substantial at the time of testing. These findings are consistent with the insolubility of cinnabar ore (*3*). However, study limitations included a small sample size, and multiple seasonal exposures were not represented. Interestingly, others have also reported higher creatinine-adjusted urine levels among females compared to males in a European subpopulation (*26*).

Participants asked if Native Americans are more sensitive to mercury and if the levels detected warrant concern. The lowest observed urine level associated with risk of renal and nonspecific neurological symptoms among those occupationally exposed is 50 µg/l (*15,16*), 25-fold higher than the observed mean. Whether there is a risk of more subtle neurological symptoms at lower levels and whether any ethnic group is at greater risk has not been characterized.

Organic mercury. Participant blood levels were much less than the lowest level, 200 µg/l, associated with increased risk of paresthesia, an early and sensitive sign of Minamata disease among adults (*4,5*). However, four women of child-bearing age had blood organic mercury values of 20–25 µg/l (Fig. 1), which begins to approach 40 µg/l. The combined results of several small studies of children exposed *in utero* led the World Heath Organization to suggest that the lowest level associated with adverse neurodevelopmental effects is 10 µg/g in maternal hair; the predicted equivalent in blood is 40 µg/l (*4*). Recent large epidemiological studies have not found adverse psychomotor outcomes, e.g., delayed onset of walking, as in the previous studies on which the l0 µg/g lowest effect level is based (*27*). However, one recent study suggests negative linear correlations with four indices of more subtle effects, e.g., perceptual performance and auditory comprehension. The median maternal hair level in that study was 7 µg/g; the predicted equivalent in blood is 28 µg/l (*28*).

Reported fish consumption is elevated: fish-consuming participants average 60 g/day of sport fish and 24 g/day of commercial fish (Table 3), compared to an average of 32 g/day of any fish among U.S. fish consumers (*14*). The average blood organic mercury level among tribal participants, 15.6 µg/l, is also higher than what others report among people who eat fish two to four times/week (8 µg/l ± 5, n = 658) and who do not eat fish (2 µg/l ± 2, n = 223) (*29*). However, the correlation reported here between blood levels and consumption of Clear Lake fish is weak (Fig. 1) and there is no correlation for consumption of commercial fish. Nevertheless, a cause and effect relationship between fish consumption and blood levels is strongly supported by the correlations reported among fish consumers worldwide (*4,29*), including larger studies of U.S. commercial fish consumers (*25*). Further, in long-term and controlled consumption studies, a strong correlation is obtained (Fig. 1) (*4,12,30*). Others also observe weaker correlations in population studies compared to controlled consumption studies and attribute the difference to fluctuating eating habits and variability in a population's metabolism compared to the constant intake and small sample of controlled studies (*31*).

The difficulty in recalling fish consumption may also contribute to the poor correlation between blood organic mercury levels and reported fish consumption in field studies. In this study, there is some evidence that fish consumption is underreported at low consumption levels. Specifically, for participants reporting consumption of Clear Lake fish under the advisory limit (30 µg Hg/day), all blood organic mercury levels are greater than that predicted by reported intake and long-term consumption studies (data points above dashed regression line, Fig. 1). Among participants whose reported intake exceeded the Clear Lake fish advisory limit, observed blood levels are less than that similarly predicted. An additional analysis also reveals that, compared to all participants, the regression line among consumers of Clear Lake fish exceeding the advisory limit is a much better fit (R^2 improved from 0.1 to 0.6), albeit the latter is nonsignificant because of the small number of individuals with blood analyses and reported consumption above the advisory limit (n = 5). Given this data and the results of other studies (*4,25,29,30*), blood organic mercury levels may be a more valid indicator of fish consumption than self-reported consumption, particularly at low reported consumption.

Mercury levels in hair have been used as indicators of past exposures, e.g., during pregnancy. Participants' levels (<1 µg/g hair) are lower than levels associated with effects among adults (50 µg/g hair) and among children exposed *in utero* (10 µg/g hair) (*3,4*). However, other studies (*4*) predict, via linear regression, that the average organic mercury blood level among tribal participants, 15.6 µg/l, would lead to levels of 4 µg/g hair, which is sixfold higher than the observed mean. There are several possible explanations: indiscernible laboratory error is one. Second, large meals of fish consumed in the few days prior to sample collection would not be reflected in hair samples. Other studies have indicated a 10-day lag between blood levels and hair samples collected at the scalp (*32*). Because our questionnaire asked respondents to average their fish consumption over the past 6 months, the occurance of such consumption cannot be explored. Such consumption, however, is a possible effect of community notification of testing prior to collection, i.e., participants may want to check the validity of the test. A third explanation is that the blood-to-hair relationship may be nonlinear at low hair levels. That is, hair values reported elsewhere are not normally distributed; they have the distinct appearance of a log-normal distribution with values clustered at the low end (*32,33*). Blood values here, however, are normally distributed. Given these distributions, the relationship between blood and untransformed hair levels should not be strictly linear. To further explore this possibility, we reviewed a study of Peruvian fish consumption; for that study, the mean organic mercury blood level among the comparison group, 9.9 µg/l, and the linear regression equation derived from the combined study and comparison population, predict, for the comparison group, an organic mercury hair level of 2.4 ppm, which is threefold higher than the reported mean, 0.78 ppm (*33*). Further exploring the blood-to-hair relationship among our participants would not be fruitful because of the small sample size, the large percentage of hair values below the detection limit, and the other possible explanations. Nevertheless, future research should closely examine all of the explanations outlined here, particularly if blood alone continues to be used for monitoring fish consumers (*25*) and epidemiological studies continue to use hair alone to define dose–response relationships between exposure and health outcomes (*28*). Because blood is a more accurate estimate of current mercury body burden (*12*), our recommendations are based on blood levels.

Recommendations

Inorganic mercury. The strength of the finding that participants' exposures to dust and soil are not substantial is constrained by noted study limitations. The CDHS recommends that people do not enter the SBMM site and that regulatory agencies continue with remediation. Additional urine monitoring in this community is not warranted unless there are indications in the future of greater exposure, e.g., unusual behavior patterns or higher environmental concentrations.

Organic mercury. The issuance of the FDA maximum tolerance intake is an attempt to restrict fish consumption and maintain blood levels 10-fold below levels associated with increased risk of paresthesia, i.e., below 20 μg/l (*11*). In addition to the fact that this tolerance ignores adverse neurodevelopmental effects to children exposed *in utero*, a 10-fold margin is most likely inadequate not only for sensitive subpopulations such as children but also for adults (*6*). Others report evidence of lower effect levels among adults for subtle neurological effects, e.g., difficulty concentrating (*34*) and difficulty in color discrimination (*35*). A recent study also suggests adverse cardiovascular end points (*36*). Based on animal evidence, others propose lowering reference concentrations to levels that would aim to maintain blood levels below 3 μg/l to protect children from adverse neurodevelopmental outcomes (*37*). Our study indicates the current blood levels within a Native American community with an existing sport-fishing advisory: 20% exceed 20 μg/l and 100% exceed 3 μg/l. For the U.S. population, estimates indicate 4% of fish-consuming adults eat enough fish to achieve a blood level of 20 μg/l or greater and 23% of fish-consuming women eat enough fish to achieve 3–4 μg/l or greater (*14*). These data indicate that a minimal 10-fold margin between adverse effect levels and observed levels is not being maintained and that a greater, more protective margin is not maintained for a substantial portion of the population. Additional protective public health efforts are necessary.

Reducing mercury emissions to the environment would provide fundamental protection. Such reduction is a long-term goal, as emissions are large (30,000 tons per year) (*3*) and mercury sediment concentrations have risen fourfold in the past century (*38*). Others call for restricting intake through lowering the federal action level for fish to 0.5 μg/g (*35*). A lower action level, however, must consider the health benefits of fish in the diet as well as the risks of adverse effects.

Sport-fish consumption advisories are the main focus of public health agency protective efforts. Recently, an interim fish consumption advisory for the San Francisco Bay was issued, in part due to mercury contamination (*39*). Greater health education efforts are also needed, e.g., dietary counseling, posting advisories at lakes, and health care provider education. The federal advisory for commercial top marine predators has not been widely disseminated. Health care providers can discuss sport and commercial fish contamination with patients, overall dietary requirements, and the benefits of cultural traditions and sport fishing. Regulatory and public health agencies must also develop consistent advice that weighs these risks and benefits.

The World Health Organization recommends biological testing of women of child-bearing age—particularly pregnant women—who consume large amounts of fish, i.e., greater than 100 g (3–4 oz) per day (*4*). As discussed above, biological testing is a more valid estimation of risk than self-reported consumption. Individual differences in biological half-life will also lead to differences in blood levels and risk. Notably, consumers who eat 100 g/day are probably a small subset of the population, as the estimated 90th percentile among U.S. fish consumers is 60 g/day (*14*). Once aware of advisories, some may request testing. However, there is no laboratory certification program for mercury in biological specimens. Such a program is highly recommended.

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