Mercury Exposure in Young Children Living in New York City

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ABSTRACT Residential exposure to vapor from current or previous cultural use of mercury could harm children living in rental (apartment) homes. That concern prompted the following agencies to conduct a study to assess pediatric mercury exposure in New York City communities by measuring urine mercury levels: New York City Department of Health and Mental Hygiene's (NYCDOHMH) Bureau of Environmental Surveillance and Policy, New York State Department of Health/Center for Environmental Health (NYSDOHCEH), Wadsworth Center's Biomonitoring Program/Trace Elements Laboratory (WC-TEL), and Centers for Disease Control and Prevention (CDC). A previous study indicated that people could obtain mercury for ritualistic use from botanicas located in Brooklyn, Manhattan, and the Bronx. Working closely with local community partners, we concentrated our recruiting efforts through health clinics located in potentially affected neighborhoods. We developed posters to advertise the study, conducted active outreach through local partners, and, as compensation for participation in the study, we offered a food gift certificate redeemable at a local grocer. We collected 460 urine specimens and analyzed them for total mercury. Overall, geometric mean urine total mercury was 0.31 μg mercury/l urine. One sample was 24 μg mercury/l urine, which exceeded the (20 μg mercury/l urine) NYSDOH Heavy Metal Registry reporting threshold for urine mercury exposure. Geometric mean urine mercury levels were uniformly low and did not differ by neighborhood or with any clinical significance by children's ethnicity. Few parents reported the presence of mercury at home, in a charm, or other item (e.g., skin-lightening creams and soaps), and we found no association between these potential sources of exposure and a child's urinary mercury levels. All pediatric mercury levels measured in this study were well below a level considered to be of medical concern. This study found neither self-reported nor measured evidence of significant mercury use or exposure among participating children. Because

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some participants were aware of the possibility that they could acquire and use mercury for cultural or ritualistic purposes, community education about the health hazards of mercury should continue.

KEYWORDS *Mercury, Urine, Children, Botanicas, Azogue (Spanish word for mercury)*

Abbreviations: ATSDR – Agency for Toxic Substances and Disease Registry; CDC/NCEH – Centers for Disease Control and Prevention/National Center for Environmental Health; EPHTP – New York City Department of Health and Mental Hygiene, Environmental Public Health Tracking Program; GM – geometric mean; MHC – Manhattan Health Clinic; NRHEEC – National Report on Human Exposure to Environmental Chemicals; $\mu\text{g/l}$ – micrograms per liter; μg mercury/l urine – micrograms mercury per liter urine; $\mu\text{g/g}$ – micrograms per gram

BACKGROUND

Toxicity of Mercury

Chronic exposure to elemental mercury vapor primarily affects the central nervous system.¹ Major symptoms include a fine tremor, psychological changes (e.g., increased excitability), and gingivitis. Other symptoms can include insomnia, loss of appetite, irritability, depression, headache, short-term memory loss, and muscle wasting.

Inhalation of high concentrations of elemental mercury vapor also damages the lungs, skin, eyes, and gingival.² Symptoms of acute exposure include cough, dyspnea, chest pain, nausea, vomiting, diarrhea, fever, and a metallic taste in the mouth. If the exposure is great enough, these symptoms can progress to interstitial pneumonitis, renal injury, increased blood pressure and heart rate, and pulmonary edema.³

Most of the available information about exposure to mercury in children concerns ingestion of organic and inorganic mercury. Little available literature addresses the exposure of children to mercury vapor (elemental). Because young children have a developing nervous system and a smaller body mass than adults, small exposures that would not be expected to affect adults may have health effects in children.⁴ Although the U.S. Environmental Protection Agency (EPA) and the World Health Organization (WHO) have established an upper reference limit for urine mercury (i.e., biological threshold) at 20 μg mercury/l urine for a normal adult population, a separate limit for children has not yet been established. Some clinical laboratories consider above-normal urine mercury levels greater than 20 $\mu\text{g/l}$ urine, whereas others use a 24-h urine specimen to define the upper limit of the reference interval as $<20 \mu\text{g}/24 \text{ h}$.^{4,5}

Botanicas

Botanicas are stores that sell herbs, remedies, charms, and religious and spiritual objects. At the time of this study, the New York state Yellow Pages listed 166 botanicas, 100 of which were in Brooklyn, Manhattan, or the Bronx.⁶

Botanicas are generally regarded as an important source of ingredients for alternative medicine therapies. Mikhail et al. has documented Latin American populations' use of alternative medicine as a complementary therapy to Western medicine.⁷ Popular forms of alternative medicine include *Curanderismo*, *Santeria*, and *Espiritismo*.⁸ These alternative therapies for the prevention or treatment of

illnesses may include, for example, amulets, special prayers, ritual baths, candles, incense, religious cards, statues, and the use of various herbs. In addition to these items, botanicas may also sell natural products, remedies, and brand name pharmaceutical or healthcare products.

Cultural Use of Mercury and Botanicas

In certain religious and traditional practices (e.g., *Santeria*, *Espiritismo*, *Curanderismo*, *Palo*, and *Voodoo*), elemental mercury is used as a charm, a ritual ingredient, or a medicine. A person may carry mercury in gelatin capsules or pouches sewn into clothing or carry mercury stored in a hollowed-out nutmeg sealed with wax. Glass amulets filled with colored water, pieces of plant material or semiprecious stones, and mercury are sold on cords worn as good luck necklaces or amulets. Some reports mention sprinkling elemental mercury in homes and automobiles, and some researchers claim that such practices are widespread among Hispanic New Yorkers.⁹ During rituals, elemental mercury is sometimes added to perfumes, oils, or candles, or used in a cauldron—also called a *Prenda*.^{10–12} Reportedly, dancers also rub mercury on their hips to improve their dancing ability.¹³

Concern about Childhood Exposure

Home contamination with mercury can occur from broken thermometers, broken thermostats, or from the accidental or intentional spilling or sprinkling of elemental mercury.¹⁴ Because mercury can easily become trapped in porous surfaces such as plaster or stucco interiors, carpeting, or cracks between tile or wood floors, it may persist in an indoor environment for several years.^{1,15}

The greatest human exposure hazard associated with elemental mercury is its vapor. Mercury vapor is heavier than air, and its concentration tends to remain high near its source. In a home where mercury has been spilled on the floor, young children, particularly those who crawl, have a high risk of mercury vapor exposure, although the dose is dependent on a variety of environmental and individual factors.¹⁶

METHODS

Working with Local Community

These agencies collaborated in a study assessing mercury exposure among NYC children less than 10 years of age:

- The Centers for Disease Control and Prevention (CDC),
- New York City Department of Health and Mental Hygiene's Office of Environmental Surveillance and Policy (DOHMH),
- New York State Department of Health's Center for Environmental Health (NYSDOH CEH),
- Wadsworth Center Trace Elements Laboratory (NYSDOH WC-TEL), and
- NYS Biomonitoring Program.

Separate institutional review boards at CDC, DOHMH, and NYSDOH gave the study preinitiation approval. Because cultural uses of elemental mercury have been reported most often in Hispanic or Caribbean groups, we used demographic information obtained from NYC census data to identify for our study of NYC

neighborhoods and clinics with a high percentage of Hispanic or Caribbean residents or patients. We selected as study sites three community-based clinics: one in Brooklyn, one in the Bronx, and one in Manhattan. DOHMH's established relationships with these community-based clinics facilitated outreach and recruitment.

Recruitment

Two weeks before data collection, we placed colorful posters describing the study in the three selected clinics' waiting areas. We used two methods to recruit participants: parents and children in clinic waiting rooms and door-to-door recruitment in one neighborhood surrounding a clinic where a number of botanicas were located. In the first method, we approached parents in clinic waiting areas to explain the study and to determine participant eligibility. Only one child per family was eligible; that child had to be under the age of 10 years and had to be at the clinic for a well-child exam.

The second method—neighborhood recruitment—occurred through home visits. The same age criteria applied, and the child could not be ill. All children who were ineligible for either the clinic or the home survey were given brochures prepared in 1999 by the NYC DOHMH describing the dangers of mercury exposure. If a child was eligible for participation, consent was requested and obtained from the participant's parent. Assent was also requested and obtained from participating children who were more than 7 years of age.

At the conclusion of the interview and sample collection, study staff thanked the parent and child for their time and, as compensation, gave the parent a \$25.00 gift certificate redeemable at a local food market. Study staff also educated both parent and child about mercury, including the various forms of mercury, how to recognize mercury, and the potential short-term and long-term adverse health effects associated with human exposure to mercury.

Procedures in the Case of Elevated Results

For this study, published biological levels served as reference values (Table 1).^{17–20} A >50- $\mu\text{g/l}$ urine screening level was established to identify children with higher mercury exposures warranting additional medical follow-up (Table 2). This level is well above background urine mercury concentrations, but well below 150 $\mu\text{g/l}$ —considered the low end of the range of concentrations associated with nonspecific symptoms.^{4,21}

Each consenting parent or legal guardian of a child enrolled from a clinic or door-to-door received a letter explaining his or her child's mercury level, and parents were also given the option of placing a copy of the results in the child's medical file. If an elevated result was confirmed on follow-up testing, the child was referred for further evaluation to the Mt. Sinai Center for Children's Health and the Environment. In accordance with New York state law, any child's elevated results were also shared with the NYS DOH Heavy Metals Registry.

Questionnaire

We administered a standardized questionnaire in English, Spanish, or Creole to parents or legal guardians of all participating children. The questions established the demographic status of the participant (e.g., sex, age, ethnicity), type of residence the family inhabited, possible sources of mercury, and whether the parent patronized botanicas. In the questionnaire, we referred to mercury by several culturally identifiable names, including the Spanish term for mercury, *Azogue*.

TABLE 1 Reference biological values

Study	Year of sample collection	Age group (years)	Sample size	Geometric mean (95%CI)	Median	95th percentile
Urine-total mercury results in µg Hg/l urine						
Seifert et al.	1990–1992	6–14 (♀♀ and ♂♂)	732	0.54 (0.50–0.59)	0.5	3.9
Pesch et al.	1996	8–10 (♀♀ and ♂♂)	224	0.26 (0.23–0.29)	–	1.62
Ozuah et al.	1998–1999	Mean 9.4 (♀♀ and ♂♂)	100	1.08	0.64	2.8
NRHEEC ^a	1999–2000	16–49 (♀♀)	1748	0.719 (0.622–0.831)	0.760	5.00
NRHEEC	2001–2002	16–49 (♀♀)	1960	0.606 (0.553–0.665)	0.580	3.99

Statistical distribution of reference values for urine mercury from several studies.
Urine mercury is expressed as µg Hg/l urine
Analytical limit of detection (LOD) for studies: Pesch et al.,¹⁹ 0.1 µg/l; Seifert et al.,²⁰ 0.2 µg/l.
♀♀: females only, ♀♀ and ♂♂: males and females
^aThird national report on human exposure to environmental chemicals (CDC), 0.2 µg/l.¹⁷

Urine Specimen Collection

From consenting/assenting children, we collected “spot” or random urine specimens in plastic urine cups prescreened for mercury. To prevent mercury losses via outgassing, aliquots of urine were transferred into 5-ml cryovials containing 50 µl of a 200-mg/ml sulfamic acid solution.²² To control for possible environmental contamination, previously analyzed pure water specimens (i.e., field water blanks) were collected daily in each clinic. These field blanks were shipped with the urine

TABLE 2 Urine mercury medical concern and intervention levels

Concern level	Urine	Intervention
Below the level of concern	<20 µg/l	No intervention required.
Mildly elevated	20 to 50 µg/l	Value is mildly elevated, but below what would be considered a health risk. Encourage parents to contact their physician or local clinic to determine and reduce their child’s exposure.
Potentially medically significant	>50 µg/l	Ask parents to return to the clinic or to go to their physician with their children for retesting. If retesting still indicates an elevated mercury level, the local health department will follow-up to identify sources of contamination and provide guidance on how to prevent exposure in the future. Medical treatment with dimercaprol or penicillamine may be necessary to prevent neurologic damage.

Levels of concern and intervention were predetermined for the study based on concentrations considered to be on the upper end of the range of concentrations considered normal and the lower end of the range associated with symptoms.^{4,21}

specimens and analyzed for total mercury using the same method. In addition, we wanted to control for any participation refusal that could result in bias. So, we collected residual urine specimens ($n=49$) of children under 10 years of age. We collected these from the study clinics and made sure that the samples did not contain identifiers. Residual urine specimens are excess materials collected as part of a standard well-child exam (e.g., glucose, urinalysis). As stated, the residual urine specimens did not include personal identifiers, and in the remainder of this document, they are referred to as anonymous samples.

Urine specimens ($n=460$) and field water blanks ($n=34$) were frozen and shipped on dry ice to the Trace Elements Laboratory at the Wadsworth Center, New York State Department of Health, Albany, NY (NYSDOH WC-TEL) for determination of total mercury. For quality control purposes, the CDC/NCEH laboratory in Atlanta, Georgia analyzed a subset (10%) of urine specimens.

Determination of Total Mercury

Urine specimens were analyzed for total mercury using inductively coupled plasma mass spectrometry (ICP-MS).²² The method has been fully validated per Clinical Laboratory Improvements Amendments of 1988 (CLIA-88) and is periodically assessed via external quality assessment schemes (EQAS) or proficiency testing (PT) programs operated by (a) NYSDOH, WC-TEL; (b) INSP, Centre de toxicology du Quebec (CTQ); and (c) the German EQAS. The method detection limit (MDL) for this technique is 0.11 $\mu\text{g/l}$. With each specimen batch four levels of quality control materials were run, and between-run (intermediate) precision ranged from 1.8% to 2.6% RSD.²² A subset (10%) of urine specimens were analyzed for inorganic mercury using an automated flow injection mercury system (FIMS) that uses cold vapor atomic absorption spectrometry.²³

Statistical Analysis

For statistical analyses of the data, we used SAS version 9.00. For all values below the limit of detection (LOD; 0.11 μg mercury/l urine), we substituted the LOD divided by the square root of 2. In an attempt to normalize the skewed distributions, we applied log transformation to urine mercury values. Because transformation of the urine mercury values did not normalize the distribution, we used nonparametric tests (Wilcoxon rank sum test to compare two groups and the Kruskal–Wallis test for more than two groups).

RESULTS

Enrollment

We collected a total of 465 urine specimens, including clinic-enrolled participants, door-to-door visits, and anonymous samples. Because of insufficient sample volume, analysis results were available for only 460 urine specimens. The samples are distributed as follows:

- 392 urine samples and 398 questionnaires from children enrolled at clinics,
- 19 urine samples and questionnaires from children enrolled in the door-to-door study, and
- 49 urine specimens collected anonymously from children at the 3 health clinics.

Overall Demographic and Residential Information

Of the children, 54% were boys and 46% were girls with a median age of 5 years (range 2–10 years) (Table 3). Of the parents, 56% reported their descent as Hispanic and 37% as non-Hispanic African American/Caribbean. Sixty-two percent reported living in apartments, 20% in 2-, 3-, or 4-unit (apartment) homes, 10% in single-family homes, and 4% in duplexes. More than two-thirds (67%) earned an annual income less than \$20,000.

Urine Levels

The measured urine mercury levels (Table 4) were all below the previously described intervention criteria (Table 2). Field water blanks were all below the ICP-MS method detection limit (0.11 µg/l). The urine mercury levels for specimens collected from the three clinics, the home visits, and the anonymous specimens are listed in Table 4. We compared the results from the clinics and the anonymous specimens and found no statistically significant difference between the two groups ($p=0.16$).

TABLE 3 Descriptive demographic data describing New York City study participants for all locations combined and stratified by clinic location and home visits

	Combined <i>n</i> (%)	BKHC <i>n</i> (%)	MHC <i>n</i> (%)	BXHC <i>n</i> (%)	Home visits <i>n</i> (%)
Characteristic	<i>N</i> =417	<i>N</i> =139	<i>N</i> =110	<i>N</i> =149	<i>N</i> =19
Sex of study participant					
Male	220 (54)	72 (53)	56 (51)	81 (55)	11 (58)
Female	190 (46)	64 (47)	53 (49)	65 (45)	8 (42)
Ethnicity					
Hispanic	228 (56)	5 (4)	90 (82)	115 (79)	18 (95)
White	1 (0.2)	—	—	—	1 (5)
Black	151 (37)	112 (85)	19 (17)	20 (14)	—
American Indian/Inuit	2 (0.5)	2 (2)	—	—	—
Asian	1 (0.2)	—	—	1 (1)	—
Native Hawaiian/Pacific Islander	1 (0.2)	—	—	1 (1)	—
Refused	—	—	—	—	—
Other	21 (5)	12 (9)	1 (1)	8 (5)	—
Type of housing					
Apartment	254 (62)	42 (31)	85 (77)	109 (75)	18 (95)
Single-family dwelling	41 (10)	29 (21)	5 (5)	7 (5)	—
2-, 3- or 4-flat homes	84 (20)	58 (43)	8 (7)	18 (12)	—
Duplex	18 (4)	6 (4)	2 (2)	9 (6)	1 (5)
Other	13 (3)	1 (1)	10 (9)	2 (1)	—
Family income					
Under \$20,000	237 (67)	58 (52)	62 (70)	101 (76)	16 (84)
\$20,001–\$40,000	81 (23)	33 (29)	24 (27)	24 (18)	—
\$40,001–\$75,000	32 (9)	18 (16)	3 (3)	8 (6)	3 (16)
\$75,001–\$100,000	3 (0.9)	3 (3)	—	—	—
More than \$100,000	—	—	—	—	—
Refused to answer	5	2	3	3	—
Didn't know/not sure	50	22	11	17	—

Missing data prevented a total of $N=417$ for most variables. Missing data were most often caused by the refusal of the participant to provide that information.

BKHC: Brooklyn Health Clinic, MHC: Manhattan Health Clinic, BXHC: Bronx Health Clinic

TABLE 4 Stratified urine mercury levels #1

Urine mercury ($\mu\text{g Hg/l urine}$)				
Sample size	Range	Geometric mean (95% CI)	Median	95th percentile
Clinics only (not including anonymous specimens)				
392	<LOD–24.0	0.32 (0.29, 0.35)	0.30	2.01
Anonymous clinic specimens				
49	<LOD–4.3	0.25 (0.19, 0.34)	0.21	1.37
Home visits				
19	<LOD–4.7	0.24 (0.14, 0.42)	0.19	4.68
Brooklyn Health Clinic				
137	<LOD–16.6	0.35 (0.30, 0.42)	0.34	1.73
Manhattan Health Clinic				
108	<LOD–13.8	0.22 (0.18, 0.27)	0.21	1.19
Bronx Health Clinic				
147	<LOD–24.0	0.38 (0.32, 0.46)	0.34	2.95

Urine mercury levels stratified by all clinics combined, individual clinic, home, or anonymous from the New York City elemental mercury exposure assessment study.

Limit of detection (LOD) was 0.11 $\mu\text{g mercury/l urine}$.

Botanicas and Mercury

Of the 398 questionnaire respondents, 38% reported that they had visited a botanica and 12% said they occasionally purchased items, including candles (34%), herbs (21%), vitamins or medicines (13%), religious items (18%), and amulets (2%). Many respondents remarked that the candles were for emergency use (often referring to the Northeast blackout of 2003). When asked if mercury metal or *Azogue* was present in their home, 1% ($n=6$), responded affirmatively. Two out of the six respondents said that at home they had charms or amulets containing mercury or *Azogue*.

Because some personal care products have been found to contain inorganic mercury, we also asked about skin-lightening lotions.²⁴ Of the respondents, 9% reported purchasing skin-lightening creams or soaps, but we could not determine whether these products contained mercury. When asked where they could purchase mercury, 88% of adults answered that they did not know. The most frequently mentioned sources were botanicas (5%) and pharmacies (3%).

When parents who visit botanicas were asked the reasons for such visits, 7% said it was a tradition in their country of origin, 5% said it was a family tradition, 32% were told about it or taken by a family member, and 34% were referred by a friend. Only 2% were recommended to the botanica by a *curandero* (traditional healer).

To understand further any connection between *curanderos*, *espiritistas*, or other healers and mercury use, we asked if mercury had ever been recommended by these traditional healers. Six parents (1.4%) said a traditional healer had recommended mercury use. When questioned further, however, none admitted having obtained or used mercury, and five of these said they did not know where they could obtain it if they wanted it. We also asked parents if they had observed mercury being manipulated. Specifically, when we asked whether they had seen children other than their own wearing glass amulets that contained mercury, 9% ($n=35$) said that they had and 4% ($n=16$) also indicated they had seen children playing with liquid mercury.

Relation Between Urine Mercury Levels and Questionnaire Variables

Persons claiming Hispanic (56%) and black (37%) descent dominated the study population with 49% of blacks reporting Caribbean heritage (Table 3). When urine mercury values were examined by ethnicity, we found statistically significant differences among these groups ($p=.04$), although all group geometric means were far below levels of concern and of no clinical significance. Black children had levels of 0.36 μg mercury/l urine. Hispanic children (0.27 μg mercury/l urine) and a combined group of Asian, Pacific Islander, and American Indian (0.26 μg mercury/l urine) children had urine mercury levels that were lower (Table 5). For all groups, sex did not correlate with urine mercury levels.

We also examined urine mercury levels by country of origin and found that no statistically significant differences appeared in urine mercury concentrations between children of U.S. and foreign-born parents ($p=0.13$).

Because persons living in multiunit dwellings could be exposed to mercury used or spilled by others, we compared urine mercury levels of residents in single-dwelling buildings to those in buildings with two or more apartments. We found no association between mercury exposure and type of housing ($p=0.85$).

We also asked the location of the botanica closest to home. Three persons said a botanica was in the same building where they lived and 204 (53%) said one was on the same block or street. Nevertheless, mercury levels were not associated with proximity to botanicas ($p=0.44$).

Participants reported purchasing a variety of items from a botanica that could potentially contain mercury or mercury salts (e.g., candles [$n=71$], skin-lightening creams and soaps [$n=37$], bath salts and floor washes [$n=18$], and amulets [$n=2$]). Mercury levels, however, did not differ between children of purchasers and nonpurchasers. We also investigated any reported use of mercury, the observation of children playing with mercury, and seeing children wearing mercury-filled amulets. We found no associations between these observations and mercury levels in children ($p=0.31$ and $p=0.13$, respectively).

TABLE 5 Stratified urine mercury levels #2

Urine mercury values by ethnicity (μg Hg/l urine)					
Ethnicity	N questionnaire responses (N urine results)	Geometric mean (95%CI)	Median	Range	95th percentile
Asian/Pacific Islander/ American Indian ^a	5 (5) ^a	0.26 (0.13, 0.51)	0.27	<LOD–0.65	0.65
Black	149 (149)	0.36 (0.30, 0.42)	0.35	<LOD–16.7	1.65
Hispanic	224 (224)	0.27 (0.24, 0.32)	0.27	<LOD–13.8	2.20

Urine mercury levels stratified by ethnicity from New York City elemental mercury exposure assessment study.

A statistically significant difference was found among these groups by the Kruskal–Wallis test ($p=0.04$). Persons who did not provide information regarding ethnicity were not included in this table.

^aBecause of the small sample size, three separate categories were combined.

Dental Amalgam

We asked parents if their child had ever visited a dentist, and 69% ($n=282$) said that they had. Of all children, 89 had no amalgams and 11% ($n=44$) had from 1 to 8 fillings. Among those with dental amalgams, the geometric mean mercury was 0.51 $\mu\text{g/l}$ compared to 0.27 $\mu\text{g/l}$ among those without amalgams ($p<0.001$). The levels in both groups were far below any reporting level or level of medical concern.

DISCUSSION

Mercury biomonitoring data are interpreted either as (1) elevation of levels relative to background or (2) by their medical significance. Measured levels are compared to background levels (i.e., reference range) of a normal population with no known, unusual exposure. Study mercury levels and comparison mercury reference range levels are determined by the same or comparable analytical methods. This is an important interpretive feature; clinically relevant values, as critical as they are, do not tell the whole story. A complete interpretation of the medical effects of mercury levels must also involve clinical evaluation.

We quantified mercury exposure in urine specimens collected from children in clinics and during home visits in selected New York City neighborhoods. We also examined questionnaire data to identify risk factors for mercury exposure. We found that mercury levels were generally far below levels of medical concern, and we identified few predictors of mercury elevation.

Unfortunately, pediatric reference values are limited for background mercury levels in urine or blood. To place our results into context, we compared our study results with biological values for urine from previous studies (Table 1). These reference values were selected because their study populations represented children of similar age distribution with no known mercury exposure. For all specimens measured in our study population, mean urine mercury levels are at or below the levels described in Tables 1 and 2. Among these only six specimens had levels that were $>5 \mu\text{g/l}$, and of those, only three specimens were $>10 \mu\text{g/l}$.

The 1998–1999 Ozuah et al. study examined mercury exposure in 100 New York City children (mean age 9.4 years) who visited inner-city health clinics.¹⁸ Mercury levels in our population were lower with the geometric mean and median in our study by one-third and one-half, respectively, of those found by Ozuah et al. The 95th percentile of our study was about 25% lower than that found by Ozuah et al. Our study included children from three counties, whereas Ozuah et al. recruited only from the Bronx. Possibly, mercury levels dropped in the years between the two studies. These differences may account for our lower findings, but noteworthy is the fact that neither study found medically significant levels of mercury in children.

We examined urine mercury values among the three clinics (Table 4); mean urine mercury values at the Harlem Manhattan Health Clinic were statistically and therefore significantly lower ($p<0.05$) than at the other clinics. Although all mean urine mercury values were below medical concern, the highest clinic mean value in our study was found at the Bronx Health Clinic (0.38 μg mercury/l urine). One subject at the Bronx clinic had a mercury result of 24.0 μg mercury/l urine—a New York state reportable level (levels $>20 \mu\text{g}$ mercury/l urine). The NYC DOHMH attempted without success to contact the family for follow-up; the address provided by the parent did not exist, the telephone was not in service, and the child had never before been seen by the clinic. A multiple directory search by last

name and first name of the parent yielded no working telephone or address in New York City. Yet the questionnaire data for this participant identified no source of mercury exposure.

As previously discussed, study participants were familiar with a variety of mercury uses. More importantly, some knew where to purchase mercury and had observed children playing with mercury or wearing charms containing mercury. Despite this knowledge and despite reports of having mercury at home, in a charm, or other potential mercury-containing item (e.g., skin-lightening creams and soaps), we found no association between knowledge of these potential sources of exposure and the children's urine mercury levels. Only the presence of dental amalgams was associated with higher mercury levels. This is consistent with previous findings.²⁵

STUDY LIMITATIONS

Two possibilities may explain the low levels of mercury exposure in our study. First, the target population may have experienced no significant ongoing exposure to mercury or the study respondents may not have used mercury in their homes. This does not mean that mercury use for cultural purposes does not occur—it does mean, however, that our study population's exposure to mercury vapor was insufficient to be quantifiable in their urine.

Second, because of nonparticipation, we could have missed ongoing exposures in our target population. We attempted to control for nonparticipation by collecting anonymous urine specimens and by working in communities with high Hispanic or Caribbean populations. In any event, the anonymous urine specimens did not differ significantly from the enrolled participants' clinic specimens.

Recently, Tsuji et al. published a paper investigating mercury exposure.²⁶ The paper suggests that when mercury exposure is at or below the ATSDR's 1- $\mu\text{g}/\text{m}$ action level for mercury vapor relative to background levels of urinary mercury,³ the contribution of mercury vapor exposure to measurable urine mercury levels may be negligible. Therefore, if mercury vapor was present in a child's environment at or below the residential action levels, it may not have been measurable in urine. But Tsuji et al. based their findings on data from occupational, not residential exposure levels. To estimate residential exposures and their corresponding urine mercury levels, Tsuji et al. extrapolated the higher occupational exposures to lower levels. In an earlier study, Mattiussi et al. suggested that at lower concentrations of mercury vapor, the relationship with urine mercury might not be linear.²⁷ Thus, according to this research, whether low residential exposures to mercury vapor will be distinguishable from baseline urine levels is difficult to say. But our study did distinguish those children with amalgam dental fillings from those without and that finding supports our position that urine testing can identify differing, low level exposures.

CONCLUSIONS

Mercury exposures—when present at all—were low in this pediatric population. Thus, among participating children who lived in communities that have the greatest concentrations of botanicas in New York City, this study identified neither widespread use nor significant exposure from ritualistic, medicinal, or other use of elemental mercury. Still, the possibility remains that elemental mercury use and

exposure is more prevalent than suggested by this study's findings. Whereas some participants reported knowing where to purchase mercury and reported seeing others use mercury-containing products, only 1% reported having mercury in their homes. In 2005, (1 year after this study was conducted) the State of New York banned the sale of elemental mercury except for research, dental, and manufacturing purposes (Laws of New York, Chapter 145, 2004). Nevertheless, the fact that some participants were aware that they could purchase and use mercury or *Azogue* suggests the need for ongoing outreach to community residents, leaders, and healthcare providers about the health hazards of elemental mercury.

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