

Assessing Elemental Mercury Vapor Exposure from Cultural and Religious Practices

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Use of elemental mercury in certain cultural and religious practices can cause high exposures to mercury vapor. Uses include sprinkling mercury on the floor of a home or car, burning it in a candle, and mixing it with perfume. Some uses can produce indoor air mercury concentrations one or two orders of magnitude above occupational exposure limits. Exposures resulting from other uses, such as infrequent use of a small bead of mercury, could be well below currently recognized risk levels. Metallic mercury is available at almost all of the 15 botanicas visited in New York, New Jersey, and Pennsylvania, but botanica personnel often deny having mercury for sale when approached by outsiders to these religious and cultural traditions. Actions by public health authorities have driven the mercury trade underground in some locations. Interviews indicate that mercury users are aware that mercury is hazardous, but are not aware of the inhalation exposure risk. We argue against a crackdown by health authorities because it could drive the practices further underground, because high-risk practices may be rare, and because uninformed government intervention could have unfortunate political and civic side effects for some Caribbean and Latin American immigrant groups. We recommend an outreach and education program involving religious and community leaders, botanica personnel, and other mercury users. **Key words:** cultural, exposure, mercury, religious, Santeria. *Environ Health Perspect* 109:779–784 (2001). [Online 1 August 2001]

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In the United States, certain Afro-Caribbean and Latin American traditions, including Santeria, Palo, voodoo, and Espiritismo, incorporate the use of elemental mercury in folk medicine and religious practice. Mercury is sold in most botanicas—stores specializing in herbal remedies and religious items used in these traditions (1,2). Its use in small, enclosed spaces and the long residence time of elemental mercury create the potential for very high direct exposures to individuals.

Although these religious traditions have been well studied by anthropologists and sociologists (3–7), mercury use and the hazards it poses to practitioners have not been a focus of this work. Popular books for home practitioners of Santeria (8,9) include spells that use mercury, but do not comment on the risks it poses. Medical anthropologists have documented the use of potentially toxic remedies in folk medicine, but have not focused on the health implications of toxic substances used in religious rituals and spells (10,11).

Availability and extent of use. Several surveys have attempted to characterize mercury use in Latino/a and Afro-Caribbean communities. In a survey of New York City botanicas, 93% reported selling elemental mercury (about one to four capsules per day) (2). A survey of 115 botanicas in 13 cities in the United States and Puerto Rico found that 99 sold mercury (1). Johnson (12) surveyed 203 Caribbean and Latin American adults in the New York City area; 44% of Caribbean and 27% of Latin American respondents

reported using mercury. However, a study of Santeria practitioners in the Hartford, Connecticut, Hispanic community done by the Agency for Toxic Substances and Disease Registry [ATSDR (13)] found only 14% reported using mercury in the home. The Hartford study was limited to practitioners of Santeria, a Cuban syncretic religion combining elements of Catholicism and the African Yoruba religion. Santeria is somewhat stigmatized and practiced covertly because of its long history of oppression in Cuba and conflict over animal sacrifice rituals in the United States (3). Johnson (12) looked more generally at folk medicine and religious and cultural practices, finding mercury use outside of Santeria; similarly, Zayas and Ozuah (2) found that Santeros (Santeria priests) were mentioned by store proprietors as the source of mercury recommendations less than 10% of the time.

Although there are no clinical studies of this population of mercury users, a recent study (14) found a 3% prevalence rate of elevated mercury levels (> 10 mg/L) in the urine of 100 children in the Bronx, New York. This rate, found among a cohort that was 55% Latino/a and 43% African-American, is comparable to the occurrence of elevated blood lead levels in similar populations, and is therefore of significant concern (14).

Uses. Mercury is typically sold in capsules that contain, on average, about 8 or 9 g (0.3 oz.) mercury (1). The most common method of use reported by botanica personnel was to

carry mercury on the person in a sealed pouch (49%) or in a pocket (32%) as an amulet; sprinkling mercury in the home was mentioned by 29%. Proprietors reported that family members, friends, spiritualists, and card readers recommend mercury to store patrons to bring luck in love, money, or health and to ward off evil (2). A survey of Latin American and Caribbean New York residents (12) found that burning mercury in a candle, mixing it with perfume, and sprinkling it in the car were also frequently reported uses. Of 28 New York botanicas visited during another survey (1), 13 prescribed sprinkling mercury on the floor. Mercury poisoning has also been documented in Mexican-American infants fed mercury as a folk remedy for gastroenteritis (15). Medical anthropologist Robert Trotter identified the use of mercury, as well as lead oxides, for the treatment of *empacho*, a culturally bound digestive illness (16).

Impacts. As a result of these practices, living spaces may become contaminated with mercury. Removal of elemental mercury from floorboards and carpets is difficult, if not completely impractical (17). These mercury practices can be a direct source of contamination not only in the users, but also in their families, people living in adjacent apartments, and any future residents of the premises. The potential liability to present and future landlords is significant, because current and prospective homeowners may raise concerns about health risks related to prior mercury use on the premises. In addition, much of the mercury used in folk medicine and religious practice may be disposed of improperly. Johnson (12) found that 64% of mercury users in his study reported throwing mercury in the garbage, 27% flushed it down the toilet, and 9% threw it outdoors.

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Sources. The wholesale sources of elemental mercury remain difficult to discern. Because the sale of mercury is not regulated in this country (although the labeling is), it could come from a number of sources.

In its initial investigation of mercury use in 1993 (18), the U.S. Environmental Protection Agency (U.S. EPA) Office of Enforcement learned that Los Angeles area botanicas, as well as retail establishments in other areas of the country, obtained mercury from a metal recycler based in U.S. Region II (New York/New Jersey area). U.S. EPA reported that this company sells a very small percentage (the exact numbers were not specified in the report) of its recovered mercury to religious supply companies throughout the country; these companies repackage and redistribute mercury, along with other religious articles, to small businesses (e.g., religious stores and candle shops) (18). Whether this is still the case in 2001 is unclear, but one botanica worker told us during our field research that the store acquired its mercury from a community member in an unlabeled truck, suggesting a less formal relationship. Several botanicas we visited poured mercury from a large container into a gelatin capsule or small bottle in front of us, often spilling it. It is reasonable to suspect that in establishments where mercury is bought pre-encapsulated, some workers either in that botanica or in a wholesaler are following similar practices, which could cause significant occupational exposures.

Botanica Field Research

The collection of qualitative data helps researchers understand how a society's belief systems are constructed and how those beliefs are legitimized. Using traditional fieldwork approaches in anthropology and sociology (observation and participant observation), we sought to understand the social, political, and cultural contexts that surround cultural and religious uses of mercury. We also attempted to understand respondents' views on mercury's "magical" properties. We visited 15 botanicas in New Jersey, New York, and Pennsylvania and engaged in conversations with the personnel there about mercury and its uses.

Our initial approach was to enlist the participation of botanica personnel in recruiting subjects for interviews. Two of us, who are white, non-Hispanic women, traveled to botanicas in Jersey City, Union City, and Passaic, New Jersey, and offered to purchase a \$10 gift certificate or store credit for every botanica customer who participated in a 20-min interview conducted at or near the botanica. However, we found that botanica personnel were wary and untrusting of us as researchers. Despite university credentials

and a detailed explanation of the study, personnel at every botanica we visited denied selling mercury. Some told us it was illegal to sell mercury, some told us that they used to sell it but no longer do because it is dangerous, and some said they simply didn't want any trouble. At the same time as botanica owners and employees denied selling mercury, they affirmed that people did use it and that store patrons requested it specifically. Possible trouble with authorities was mentioned by workers at all northern New Jersey botanicas. When asked what they meant by trouble, most were vague and said that law enforcement authorities were "cracking down." No one mentioned a specific instance of a botanica having problems with the law—just that they had heard that it was happening.

Several factors affect immigrants' willingness to participate in interviews or even to provide information to social researchers. Anti-immigrant sentiment (both real and perceived) makes possible respondents wary of outsiders, especially those who may be seen as representing authority. This difficulty may be exacerbated in urban areas where immigrant group solidarity is reinforced through differences in cultural knowledge between insiders and outsiders. To the extent that a group uses racial and ethnic markers to determine inclusion or exclusion, researchers who are not group members may find themselves excluded automatically.

One week after our first attempt, a member of our research team who is an Afro-Cuban Santero returned to these botanicas by himself and was able to purchase mercury in all but one establishment (Figure 1). Some shared with him the fact that "inspectors" had been by (the same day that the first two researchers visited, so this may have been a reference to them), and they expressed concern about trouble from the authorities. Some of these botanicas sold mercury directly, whereas others used more clandestine approaches, such as sending the researcher to a private home or offering to meet him later with some mercury from a "personal stash." Even those that sold directly were surreptitious about the location of mercury in the store, keeping it out of plain sight and in some cases obscuring the location from the purchaser.

This climate of caution in northern New Jersey may relate to activities of the New York City Health Department in trying to educate botanicas in the city about the need to label mercury. The Health Department's program currently is extremely cautious, comprised of a letter explaining to botanica owners that they may sell mercury but must abide by labeling regulations (19), and of visits by health inspectors that involve observation only, with no violations issued or remedial actions taken (20). Despite this

reserved approach, rumors of investigations by various inspectors were prevalent in that area, making the sale of mercury more of an insider activity.

Outside northern New Jersey, it was much easier to purchase mercury. In central New Jersey, a trip by all three researchers to a local botanica revealed a much freer attitude about the substance. The mercury was stored in plain sight on a shelf behind a glass case, and the shopkeeper pulled out a glass jar containing approximately 4 lb mercury. Without using any kind of dropper, the shopkeeper poured mercury from the jar into a gelcap, with almost as much mercury overflowing onto the counter, beading and rolling onto the floor. The shopkeeper swept the remaining mercury back into the bottle with her bare hand. This botanica worker suggested several uses of mercury that were consistent with those in the literature, including sprinkling it indoors, mixing it with face cream, and burning it in a candle. Botanicas in Philadelphia were somewhat reluctant to sell mercury, but it was far easier to obtain than in northern New Jersey. A botanica worker in North Philadelphia poured approximately 50 g into a small jar for sale to the Santero researcher (shown in Figure 1). A different establishment in the same area poured it into a small zip-lock bag (also shown in Figure 1), because they were out of gelcaps. Although the owner of another central New Jersey botanica did not have mercury on hand, he volunteered to get some for one of the non-Hispanic researchers before her next visit to his shop.

A trip to a pagan/New Age spirituality store in New Hope, Pennsylvania, revealed that the use of mercury extends beyond Latino/a or Caribbean culture. A shopkeeper there told all three researchers that pagan traditions of European origin include filling a hollowed out nutmeg with mercury as a good luck charm. This shopkeeper did not have mercury readily available, but offered to travel to a botanica in New Jersey or Pennsylvania to order it for us.

In addition, we held conversations with *babalawos* (Santeria high priests) in Jersey



Figure 1. Containers of elemental mercury purchased at botanicas in New Jersey, New York, and Pennsylvania include gelcaps (weighing 10.8 g, 12.5 g, 7.4 g, and 9.3 g), jar, reused perfume bottle (teflon seal added after purchase), and plastic zip-lock bag.

City, New Jersey and Miami, Florida about how they prescribe mercury. The *babalawos* acknowledged the ready availability of mercury and expressed some concerns about the safety of its use by individuals. One said he prescribed mercury only for outdoor use. Both said that it was a spiritually powerful substance that should be used only to resolve more serious problems.

Despite the difficulties, this preliminary research provides several insights. Future research will demand careful attention to developing rapport and establishing relationships with respondents. Government efforts of the recent past have only made current and future work in the community more difficult. To the extent that there are (or people believe there are) negative repercussions for botanicas that sell mercury, a closed community becomes even more closed. The combination of racial and ethnic, religious, immigrant, and regulatory factors interact to make data collection—or preventive outreach activities by outsiders—extremely difficult.

The contrast between the interactions of botanica personnel with the non-Hispanic white researchers and those with the Afro-Cuban Santero researcher is stark. In areas where community members are wary of repercussions, researchers must work with a relative “insider.” Several botanica personnel commented to the Santero researcher that although they had to be cautious, they would sell him mercury because he was an Afro-Cuban Santero and they understood that he had a legitimate need.

Interviews with Mercury Users

We recruited individual mercury users for interviews intended to reveal how they use it, what benefits it brings them, and what they believe the risks are, if any. Knowing that cultural uses of mercury do carry some social stigma, we sought to minimize normative expectation effects by using an open-ended, structured interview, designed to capture individuals’ beliefs about mercury use (21,22).

We recruited subjects on the Internet and through newspaper advertisements; they received \$10 compensation for participating in 20-min interviews, for which they gave prior informed consent. Response was low, reinforcing the need for ethnographic approaches that reach this small target community and cross-cultural barriers more effectively. Nevertheless, the three interviews we were able to conduct illustrate a wide range of self-reported uses of mercury in a variety of cultural and religious traditions, with a range of possible exposure patterns. Here we describe two of the interviews, which present cases of high exposure and low exposure.

Subject 1. The first subject described playing with mercury as a child, and reported that 30 years later, in 1997, he “went to Cuba and I converted religions and I began using it in a religious and magical way.” He distinguished between elemental mercury and *precipitado rojo*, which he said is mercuric oxide. He said he used one or the other form of mercury about once a week, typically mercuric oxide. When asked about the benefits of mercury, he said, “mercury is used as a magical and religious thing. What it does is it speeds up magical spells. And it allows spirits to travel over water.”

He described a secondary practice he learned in Mexico City, where mercury is sold in small vials sealed with wax, for people to wear around their neck. He said he didn’t know “what they do magically,” but he hypothesized that “They might make a person’s mind quicker, you know, the association like quicksilver—the mind is quick.”

This subject’s primary use of elemental mercury was in birthing a *prenda*.

Prenda is in the Palo religion. It’s like a big cauldron. And it has a spirit in it. And to start the *prenda* you need to put at least a kilo of mercury in there. That’s when you first begin, along with a lot of other things. OK a lot of other things. One of the things that goes in there is like a *kilo de azogue* [a Spanish word for mercury]. And so it goes in there. That’s the very first thing. Then as you go along sometimes your *prenda* will ask for more mercury. Sometimes you’ll be doing a spell and you’ll need the spirit to move across water. And then you need mercury.

When asked if he would recommend mercury to a friend, he said it depended on the person and the proposed use. “Mercury is extremely poisonous and extremely toxic. Bad for people and bad for the environment.” When probed further about concerns people have about mercury, he added, “It’s like mercury is a heavy metal. It’s like mercury is an extremely toxic metal. So yeah. And you know it’s like lead in paint, there are all sorts of problems with mercury.” He said he did not know any specific symptoms that can result from mercury use, “But I know that death is one and madness is another, like mad as a hatter. They used to use mercury to [make?] felt hats so madness is probably one of the symptoms, I hope you don’t think I’m mad.” When asked how he became aware of his concerns, he said, “Well, I don’t know. Everybody knows about it.”

When asked what actions he took in response to his concerns, he said he didn’t feel he had to, because “I don’t deal that much with mercury.” He did raise concerns about disposal of mercuric oxide other than pouring it down the drain. He added, “The one concern that I do take is I don’t touch the powder and I don’t touch mercury itself

with my hand, I don’t taste it. So that’s the precaution I guess I take now because I know mercury’s toxic but I didn’t take as a child, so I guess I do take that precaution.”

Subject 2. Subject 2 was a 58-year-old Caucasian male who said he currently used mercury in magic, and also had played with it as a child. He said he used mercury once every 2 or 3 months. He said he used mercury as “an expediter” and primarily in the form of red mercuric oxide. “Basically it’s a good expediter in speeding up the action of a spell.” He said he learned magic in a school in New York in the 1970s and described mercury’s mode of action as follows: “Mercury is a symbolism of the planet Mercury which is the messenger. . . . in Greco-Roman [tradition] it relates to Mercury or Hermes. OK. But basically it’s a speeder of communications, ease of communications or communications spells, to make them pass into the subconscious mind of the person you’re doing the spell on faster.”

When asked about other uses, he shared some knowledge of Santeria and Palo, and of its use in folk medicine.

I know people use it for ulcer medication which I think is a little dense. For, like a stomachic? And they take it in a capsule form, but I don’t think that’s a very good thing. . . . [Interviewer asks why] Well, mercury’s toxic. And there’s a problem with taking anything like that internally. The other thing is when you have a toxic thing internally, mercury is a cumulative toxin that causes cavitation of the brain. And so as a result, people get a little stupid when they take mercury. Are you familiar with the phrase mad as a hatter? . . . then you know what happens to people who use a lot of mercury.

He said that “practically every magician I know uses it.” When asked if there were alternative products that brought the same benefits as mercury, he said it depends on the type of spell, but that “celery seed is a vegetable expediter” that works well, but not as well as mercury.

He said he bought a kilogram of mercury in New York City in the 1970s and that he is still working on the same quantity. He reported keeping it in a shatter-proof glass container with a teflon seal. He said he used one small drop at a time, and described two spells, one against thievery and one to promote talking.

Both spells involved putting one drop of mercury, about one-eighth inch in diameter, roughly 0.25 g, dispensed with an eyedropper, in a bottle with a narrow neck, covering it with holy water and other ingredients (feathers or ashes). The bottle is sealed with paraffin and put in a window or corner of the room (30 ft × 18 ft, no open windows or doors).

He said that the spells are typically disassembled after a week or two and that he salvages the mercury and reuses it in future spells.

"I use the same mercury over and over again. That's why I still have most of what I bought."

When asked about concerns around mercury use, he said,

Many people are concerned it plays havoc with your mentation. And as long as I've been using it I've been in MENSA or was in MENSA for about 20 years right after they first started it and I just stopped paying my dues so I don't belong to it any more but I don't think it ever hurt my mentation.

When asked specifically about health effects, he said,

Well, you know, I don't eat it, so I don't think it would be so bad, you know I wouldn't be too concerned about it.... You know, it rots your brain if you get too much of it in.

He described his precautionary behavior as follows:

Well I use a medicine dropper to move it around. Sometimes I use a spoon if I'm going to give somebody some, and I have a plastic impermeable spoon for that that I do that with, I do that with other things too.

Exposure Assessment

The literature on indoor air-quality modeling does not include models for characterizing the fate and transport of mercury vapor in homes, despite literature documenting cases of mercury vapor poisoning in indoor air, primarily from accidental spills (23–27). However, an extensive literature on modeling indoor air quality for volatile organic compounds can be built upon to estimate the fate and transport of mercury vapor indoors (28–32). An unpublished paper modeling the breakage of a common household fever thermometer (33) provides some relevant examples for modeling indoor concentrations of mercury vapor. Perhaps the most relevant work was done by the U.S. EPA's (18) adaptation of its Multi-Chamber Concentration and Exposure Model for cultural uses of mercury. The risk assessment estimated exposure for two scenarios, one in which mercury is burned in a candle and another in which mercury is sprinkled twice a week in a child's crib for 2 years.

An accurate and detailed assessment of the fate and transport of mercury vapor inside a house, including adsorption and desorption behavior, is complex and case-specific, and requires data for a variety of variables such as the surface area of exposed mercury as well as adsorption and desorption characteristics. Lacking these data, we use simple models and laboratory experiments to provide an order-of-magnitude estimate of exposures that could result from cultural uses of mercury. Although use of both elemental mercury and mercuric oxide has been reported, the calculations are for elemental

mercury because it is significantly more volatile than mercuric oxide (34).

A simple box model can provide an estimate of potential mercury vapor concentrations:

$$V dC/dt = S - QC, \quad [1]$$

where V is the room volume (cubic meters), C the concentration of mercury (micrograms per cubic meter), S the rate of mercury evaporation (micrograms per hour), and Q the air flow rate from the room (cubic meters per hour; the room volume times the number of air changes per hour). Assuming an initial mercury vapor concentration of zero, Equation 1 has the solution

$$C(t) = S/Q(1 - e^{-Qt/V}). \quad [2]$$

The mercury evaporation rate S is the rate of mercury volatilization per unit area of mercury, which is $7 \mu\text{g}/\text{cm}^2/\text{hr}$ at 20°C (35), times the surface area of exposed mercury. In this model, the equilibrium concentration is approached after several times the characteristic time V/Q , which is simply the number of hours per air exchange, typically 2 hr (36). The equilibrium concentration is S/Q .

The mercury vapor concentrations in our estimates can be compared with a number of health standards. The ATSDR's minimal risk level is $0.2 \mu\text{g}/\text{m}^3$, which is an estimate of the daily human exposure that is likely to be without appreciable risk (37). Occupational exposures can be considerably higher: The U.S. Occupational Health and Safety Administration's maximum ceiling concentration is $100 \text{ mg}/\text{m}^3$ (38). The U.S. National Institute of Occupational Safety and Health sets its 8-hr time-weighted average (TWA) recommended exposure limit at $50 \mu\text{g}/\text{m}^3$ (39). In 1994 the World Health Organization reduced its exposure limit for total inorganic mercury to $25 \mu\text{g}/\text{m}^3$, and the American Conference of Government Industrial Hygienists set its maximum 8-hr TWA concentration at $25 \mu\text{g}/\text{m}^3$ (40).

Subject 1 reported keeping a kilogram of mercury in a cauldron (*prenda*) in a 43 m^3 room. Although in the Palo religion this vessel is typically sealed, the subject did not report sealing it. Assuming the cauldron is 25 cm in diameter and that the air exchange rate in the room is 0.5 air changes/hr, the equilibrium concentration is on the order of $600 \mu\text{g}/\text{m}^3$, which exceeds occupational exposure limits by an order of magnitude.

Subject 2 reported keeping mercury in a sealed bottle and removing only small amounts for use. The room volume was an estimated 180 m^3 . Assuming a small open bottle containing only 0.25 g of mercury in a single droplet, Equation 2 indicates that

the mercury vapor levels would be on the order of $0.02 \mu\text{g}/\text{m}^3$, an order of magnitude less than the ATSDR's minimal risk level.

Applying Equation 2 to a hypothetical scenario in which a typical 9 g capsule of mercury is broken in a typical living room of 40 m^3 , we assume an air exchange rate of 0.5 air changes per hour and an average droplet diameter of 1 mm. The concentration of mercury equilibrates at about $7 \mu\text{g}/\text{m}^3$, an order of magnitude higher than the ATSDR's minimal risk level, but an order of magnitude less than the occupational exposure limits. This exposure could be significantly higher and could continue for a number of years if mercury capsules are dispersed about the house regularly.

These estimates are consistent with measurements of indoor air mercury levels after mercury spills. In 1989 two children developed acute mercury poisoning, and mercury vapor levels of $50\text{--}400 \mu\text{g}/\text{m}^3$ were found in their apartment (24). It was discovered that the previous tenant of their apartment had, several months earlier, spilled a large jar of mercury (24). In another incident, a spill of about 300 g of mercury produced indoor air mercury concentrations of $10\text{--}40 \mu\text{g}/\text{m}^3$ several months after the spill, and a child was acutely poisoned (25). Breakage of a clinical thermometer onto a vinyl kitchen floor, followed by a clean-up of all visible mercury beads, produced mercury vapor levels throughout the house of about $5 \mu\text{g}/\text{m}^3$ a week after the spill. That level fell to about $0\text{--}2 \mu\text{g}/\text{m}^3$ 2 weeks after the spill (17).

The act of burning of mercury in a candle has been reported by several sources (8,9,12) and in our field research. The high temperatures of the flame and even the melted candle wax would, upon initial examination, be expected to increase significantly the volatilization rate for mercury. The U.S. EPA estimated a maximum air concentration of $2,000 \mu\text{g}/\text{m}^3$ for a mercury-in-candle scenario (18), assuming total volatilization of 4 g of mercury in 1 min in a 27 m^3 room.

Our experiments indicate that such rapid volatilization is improbable, because mercury sinks into the candle wax and becomes trapped. Small amounts (3–12 g) of mercury were weighed out and placed in 14 tealight candles, which burned for 1 hr. At the end of this time, the candles were extinguished, and after cooling, the candle was lifted out of the tealight casing to retrieve the mercury that had sunk to the bottom of the candle. The retrieved mercury was reweighed. Figure 2 illustrates our experimental results, with losses averaging $0.09 \text{ g}/\text{candle}$. There is a systematic error caused by the possible loss of mercury in the retrieval, accounting for as much as 0.1 g of the measured losses.

Our experiments certainly rule out the volatilization of a large fraction of the mercury, contrary to the U.S. EPA. However, our data do not rule out the possibility that as much as about 0.05 g of mercury is volatilized when mercury is poured into a candle. This is at least two orders of magnitude higher than what would be volatilized at room temperature. Thus, we cannot rule out the possibility that burning mercury in a candle indoors could cause significant exposures to mercury vapor, much higher than those encountered by sprinkling mercury at room temperature.

The results of our simple models indicate that mercury exposures from some cultural uses of mercury may be below the level of health concern, but that dangerously high mercury levels could develop in a home if large amounts, high temperatures, or frequent activities are involved.

The greatest source of uncertainty in our estimates rests with the choice of a volatilization rate for mercury, which depends on temperature and droplet size (surface area). In many cases the order of magnitude of the droplet radius determines the order of magnitude of the mercury exposure, and thus is a most critical factor, which is likely to vary greatly from use to use. For example, an average droplet diameter of 1 mm was assumed in the capsule-sprinkling scenario. Average droplet size can be as small as 0.1 mm in diameter, which greatly increases the amount of mercury that can volatilize through increased surface area. Other important factors such as temperature, oxidation, and settling of dust and other particles can each affect the volatilization rate as well as the adsorption and desorption rates.

Recommendations

Our interviews, field research, and modeling show potential for cultural mercury uses to produce high exposures to mercury, and for long-term exposures that could adversely affect children living in contaminated buildings.

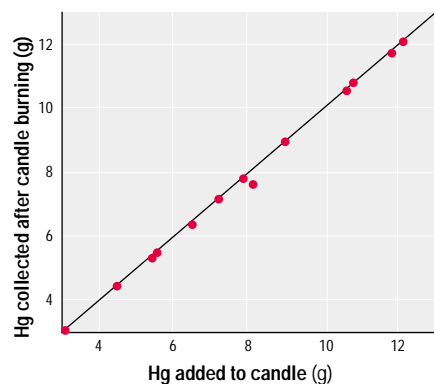


Figure 2. Mass of mercury after burning candle versus mass of mercury placed in candle.

However, we also show that infrequent practices with small amounts are not likely to pose a health hazard. It is therefore imperative that we develop a better understanding of the extent of different uses and their likely impacts on mercury air concentrations in residences. We are concerned about people's right to know if their residence is contaminated with mercury, even at relatively low levels. Finally, because our interviews showed a lack of understanding about mercury volatilization and inhalation as a route of exposure, there is an opportunity to reduce risk through community outreach and communication, with minimal interference in people's religious beliefs and cultural traditions.

Better understandings of extent of different uses. Our interviews and fieldwork indicate that mercury is used in a variety of ways by many different kinds of people. How mercury is used greatly affects the likely exposures that can result. It is imperative that social science researchers work with natural scientists to understand the prevalence rates of different mercury practices, and then relate reported or observed behaviors to exposures and health consequences, using predictive models.

Public policy. The policy implications of this work span a variety of topics from immigrant experience in the United States to labeling regulations for the sale of toxic substances to First Amendment freedoms. A key issue for regulators is the closed nature of the community. Visitors from outside the group (e.g., health inspectors) will very likely be told what they want to hear, which is: no *azogue* [mercury] here! The stricter the enforcement actions, the further underground mercury sales and use will go. Although this may reduce mercury exposure in botanicas, it may not have a significant effect on home use and thus on exposure.

Although it is currently legal to sell mercury in any environment, there are labeling requirements that should be followed—and typically are not followed in botanicas. The Consumer Product Safety Commission (CPSC) is charged with enforcing these regulations under the Federal Hazardous Substances Act (19). The CPSC, however, is notoriously underresourced, with six inspectors charged with enforcing all product regulations for over 15,000 types of products in New York City, Long Island, and northern New Jersey. Therefore, its enforcement efforts have focused on the suppliers of mercury, warning chemical companies that if they sell to botanicas or other entities that sell mercury to consumers, they must ensure those products are labeled for retail (41). The New York City Health Department has sent a similar letter to all

local botanicas explaining these labeling regulations as well as its own ordinances.

Further enforcement action would require inspectors to visit botanicas. Such a visit could produce a warning or fine or a requirement for remedial action. Current enforcement efforts in New York City have already driven mercury sales underground in northern New Jersey. They have not stopped the sale or use of mercury.

Although we support labeling of mercury (in Spanish, English, and Haitian Creole, at appropriate literacy levels), we caution against a heavy-handed approach at this time, when there is no evidence directly linking cultural and religious mercury use with adverse health effects. Inspectors' visits are often perceived by the botanicas as adversarial, and these will likely have a negative effect on relationships with the community, lower the credibility of public health authorities and other government officials in the community, and lessen their effectiveness on other important community health issues. If the common practices of mercury use are those that cause minimal exposure, government intervention could unnecessarily bring additional strain on the tenuous relationship authorities have with many immigrant groups. Because mercury is not generally controlled in the United States, government intervention in these activities could very well constitute a violation of First Amendment rights to free exercise of religion, public health risks notwithstanding (42).

At the same time, immediate steps must be taken in the research community to characterize the extent of exposure that results from these uses. Reducing the uncertainty related to this issue in a timely manner is of utmost importance, so that regulators, backed by good data, can take appropriate action. This much-needed evidence includes clinical data on mercury levels in children, better evidence on frequency, amounts, and prevalence of use, and a better understanding of the relationship between these data and resultant air levels.

If high-level exposures are found to be widespread, long-term contamination of residences in urban areas with high immigrant populations could be an explosive environmental justice issue. Those responsible for contamination may not be able to afford remediation costs. A requirement to test buildings upon sale for mercury (and a duty to inform buyers and tenants)—similar to laws for lead or radon in some states—might be a reasonable locally implemented policy for identifying contaminated homes. The recent discovery of mercury contamination in the basements of Chicago homes caused by gas-pressure regulator replacement adds political weight to this proposal. Routine testing of children for mercury levels, as they

are tested for lead in some states, is another sensible and practical response.

Risk communication. Our interviews, though quite preliminary, indicate a lack of knowledge about the inhalation pathway as the primary route of mercury exposure. People seem to know that mercury is toxic and avoid touching or eating it in most cases, but they do not seem to know about volatilization and inhalation exposure.

Several education efforts have been undertaken in the past at local and national levels. In 1993 the Connecticut Department of Health Services initiated an education campaign in Hartford, assisted by the ATSDR and the Hispanic Health Council (43). This campaign was directed specifically to cultural and religious uses. U.S. EPA and the New York City Department of Health later developed their own resources based on this material (44). The U.S. EPA has also undertaken generalized mercury education in response to incidents involving school children (45).

A redoubled effort for risk communication, directed at all U.S. residents who may encounter mercury (most commonly perhaps through broken thermometers), should emphasize the knowledge gap regarding vapor inhalation to increase general awareness of mercury's exposure routes. Specific communications for communities that engage in religious and cultural uses can also be designed and distributed, in cooperation with neighborhood religious leaders. Because of the closed nature of the community and the secrecy of practice, these communications should also have a broad and general focus, applicable to many different types of exposure.

Labeling should be an integral part of a risk communication campaign for consumer mercury use. However, label warnings must pass multiple hurdles in order to be noticed, read, understood, and ultimately heeded (46–49). Because many factors will affect a person's decision to use or not use mercury, slapping a label on a mercury-filled gelcap is not likely by itself to reduce exposure significantly. But a good label can be effective when reinforced with other outreach efforts in a coordinated public health campaign.

Community involvement, outreach, and education. Because botanicas represent a critical link to health care services in Latino/a and Afro-Caribbean communities, it is important to recognize the role of botanicas in providing culturally congruent health interventions in their communities (2,50,51). Botanicas are the first place many turn for general health care services in Latino/a and Caribbean communities; any public health interventions to reduce mercury exposure must work with spiritualists, Santeros, and botanica proprietors. Working

cooperatively with botanicas to promote effective substitutes and institute labeling for mercury is more likely to be effective than an adversarial enforcement approach that essentially criminalizes cultural practices. Outreach in Afro-Caribbean and Latino/a communities is recommended. Such outreach and education will be most effective if they are coordinated with an effort to characterize the ways mercury use and its hazards are understood in the communities, so that communications can address any gaps in knowledge and provide the most salient information to mercury users.

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