Session No. 728

Responding to Residential Elemental Mercury Contamination

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Introduction

Elemental mercury contamination of residences, schools, healthcare facilities and workplaces occurs with more frequency than one would think. In one year, the Rhode Island Department of Environmental Management (RIDEM) responded to seven reported elemental mercury spills (RIDEM, 2005). Over a five year period (2000 – 2004), RIDEM recovered 506 pounds of spilled elemental mercury (NEWMOA, 2001, p. 2).

This study analyzed the response to a residential elemental mercury contamination incident in Rhode Island. That incident resulted in evacuation of an entire apartment complex, temporary relocation of 140 residents and subsequent investigation of 130 additional sites in 15 cities across two states.

Purpose

The goal of this study was to make evidence-based recommendations for responding to future incidents involving residential elemental mercury contamination. The objectives were:

1. To increase the efficiency and expediency of future responses;
2. To minimize secondary contamination of evacuation sites;
3. To facilitate a more timely return of residents to their homes; and
4. To assure the residents that their homes are safe once again.

Method

The methodology employed for this study included: examining all response-related documents, interviewing key government and contract personnel involved in response, reviewing and evaluating current national and state departmental policies and procedures and extracting and compiling large amounts of environmental monitoring data that were collected during specific phases of the response for in-depth analysis. A review of the scientific literature was undertaken prior to commencing this study.

Hazards of Mercury

Mercury can exist in three forms: elemental (Hg^0), inorganic (IHg or Hg^{+1}, Hg^{+2}) and organic e.g. methylmercury (MeHg). Humans have daily contact with both naturally-occurring and anthropogenic sources of elemental mercury (U.S. Geological Survey, 2000). Mercury has been measured at or above detectable levels in air, water, and food, in places where people live, work, play, and learn, in products purchased and equipment used (EPA Great Lakes Region, 1998). Outdoor urban air has 10 – 20 ng/m^3 mercury concentration (Singhvi, Mehra, & McGuire, 2004). In 1998, the U.S. Environmental Protection Agency established an air reference concentration (RfC) for elemental mercury at 300 ng/m^3 (U.S. EPA, 1999). A reference concentration is an estimate of continuous inhalation exposure in a human population (including vulnerable subpopulations) that is likely to be without appreciable risk of deleterious effects during a lifetime (U.S. EPA, 1998).

Residential elemental mercury sources include thermometers, thermostats, heating oil, coal, regulators e.g. gas delivery systems, switches, fluorescent light bulbs, automobiles, and cell batteries (U.S. Geological Survey, 2000). Additionally, mercury has been incorporated into certain sociocultural behaviors and ritual practices that can occur within a residence (U.S. EPA, 2002). There are little data available regarding background levels of mercury in residences. One environmental survey of twelve New York residences suggested that indoor sites may have higher concentrations than those outdoors (Carpi & Chen, 2001). However, the study suggested that short-term monitoring was not sufficient to adequately characterize the degree of background residential contamination due to large seasonal changes.

Mercury persists both in the environment and in the human body. Elemental mercury vaporizes at room temperatures. As a result, exposure to elemental mercury occurs primarily through inhalation and to a lesser extent through skin absorption or (secondary) ingestion. Eighty percent of inhaled Hg^0 enters the bloodstream then travels to the brain and kidneys where it accumulates (Cherian, M. G., Hursh, J. B., Clarkson, T. W., & Allen, J., 1978). Exposure to high levels of Hg^0 vapor can cause symptoms such as irritation to the lining of the mouth, lungs and airways, increased blood pressure and heart rate, and/or nausea, vomiting and diarrhea. Even a small amount of Hg^0 remaining in a room after a spill can continue to vaporize slowly over time resulting in sustained elevated air concentrations of mercury and chronic exposure. Early symptoms of chronic mercury exposure include loss of sensation in the extremities and constriction of the visual field. More severe symptoms include emotional lability (irritability, shyness, nervousness), tremors, muscle incoordination, memory loss, deafness and eventually, total incapacitation and death (Agocs, M., & Clarkson, T., 1995). Depending upon the dose and the individual, the latency period between exposure and the appearance of symptoms may span weeks. Because Hg^0 is slowly excreted from the body, it accumulates in the kidneys which are particularly sensitive to damage. Little to no information is available regarding health effects associated with low level long term mercury exposures. (CDC ATSDR, 1999.)

As mercury bioaccumulates in the body, there is the potential for transgenerational consequences. Mercury crosses the placenta easily. Fetal exposure results in more severe disease manifestation than adult exposure. Effects can range from subtle decrements in development or intelligence to acute and chronic developmental disabilities such as cerebral palsy, kidney, immune and/or reproductive system disorders and an increase in the likelihood of heart disease. Fetal damage has been reported in cases where their mothers did not exhibit overt symptoms. (Clarkson, T. W., Magos, L., & Greenwood, M. R., 1972.)

Among infants and toddlers, postnatal exposures occur through lactation and general hand-to-mouth contact. Additionally, children are closer to the floor or ground where mercury vapor concentrations tend to be higher. Acrodynia occurs in a small percentage of the general population;

it is often seen in children. Acrodynia is an idiosyncratic hypersensitivity hallmarked by bright pink or red hands and feet with peeling skin (Weinstein, M., & Bernstein, S. 2003).

Biomarkers for organic and inorganic mercury exposure are available. Mercury can be detected in blood (mostly MeHg), urine (Hg^0 and IHg), feces, exhaled breath (Hg^0) and hair (MeHg). Laboratory analysis of blood mercury can be speciated (organic vs. non-organic). (Langworth, S., Elinder, C., Gothe, C., & Vesterberg, O. 1991.) Epidemiological studies have demonstrated health effects at blood concentrations below so-called "safe" levels (< 10µg/L in blood) (Axelrad, D. A., Bellinger, D. C., Ryan, L. M., & Woodruff, T. J., 2007).

Site of Contamination

The site of contamination was the Lawn Terrace Apartments in Pawtucket, RI. The apartment complex is adjacent to property owned by the gas company. The complex is comprised of five apartment buildings and one smaller maintenance building (Burns & McDonnell Engineering, 2005). There are twelve apartments in four of the buildings; there are six larger apartments as well as the complex's laundromat in the fifth building for a total of 56 apartments. The complex is referred to as "project-based Section 8 Housing" as these units alternate between subsidized housing and open market, depending upon the individual renter(s).

Summary of Events

On October 22, 2004, local authorities notified the Rhode Island Department of Environmental Management (RIDEM) of an elemental mercury spill in a storage shed owned by the natural gas company, Southern Union, the result of vandalism sometime within the prior three to four weeks. An estimated 25 pounds of mercury were missing; an equal amount had been spilled inside the storage shed. RIDEM notified U.S. EPA Region I office since the EPA Reportable Quantity for elemental mercury is one pound. (As a reference, one pound of elemental mercury is equivalent to two tablespoons or 29.57 milliliters and 26 pounds is equal to one quart.) At an adjacent apartment complex comprised of six building and 54 units, a maintenance employee told authorities about beads of mercury in the complex parking lot (Marcelo, 2008.)

Environmental Protection Agency Emergency Response Guidelines

U.S. EPA emergency response guidelines for residential mercury contamination were available to responders at the time of the incident (Singhvi, Mehra, & McGuire, 2004; U.S. EPA Region 5, 2001). These guidelines were based on lessons learned from a number of responses. The six R's:

1. *Referral*. The roles, responsibilities and authorities of local, state and federal agencies are delineated. This section addresses consent for entry and access to property. (In this case study, RIDEM, U.S. EPA Region 1, Rhode Island Department of Health Office of Environmental Health Risk (EHEALTH) assumed joint command.)
2. *Reconnaissance*. Procedures are detailed for initial assessment of the extent and degree of contamination present in the residences.
   a. Agency for Toxic Substances and Disease Registry (ATSDR) action level for cleanup is 1,000 ng/m^3 (Singhvi, Mehra, & McGuire, 2004, p. 9)
   b. Personal Protective Equipment Level C (air-purifying respirator) required for air levels ≥ 25,000 ng/m^3 (Singhvi, Mehra, & McGuire, 2004, p. B-v)

3. *Relocation*. Residents should be temporarily relocated if assessment and clearance screening level (ACSL) is > 10,000 ng/m^3 real-time or > 1,000 ng/m^3 eight-hour time-weighted average. (See Table One.) A step-by-step process is outlined for screening residents' clothing prior to relocation.

4. *Removal*. The lengthy process of documenting and decontaminating residences, their contents and surrounding property is provided.

    a. Action levels for soil remediation are referenced. (See Table Two). Disposal characterization is detailed, e.g., waste manifests.

5. *Replacement*. Residential restoration should return each residence to its prior condition and repair damage secondary to decontamination procedures. The EPA has the legal authority to recover costs under Superfund though they are reluctant to do so when it involves a residence. In this case study, the gas company assumed full financial responsibility. Replacement will not be discussed further in this paper.

6. *Reoccupation*. Again, the roles, responsibilities and authorities of local, state and federal agencies are delineated. It addresses by whose authority residential reoccupation is allowed. Typically, representatives from all of these agencies meet with residents prior to and following reoccupation.

    a. Residential Occupancy Level (ROL): 1,000 ng/m^3 as an eight-hour time-weighted average. When post decontamination levels by direct reading instrumentation are within acceptable limits, eight-hour time-weighted samples are taken. If these samples are < 1,000 ng/m^3, then re-occupation can occur.

Direct Reading Instruments

There were a number of direct reading real-time instruments available for detecting elemental mercury vapor (Rader Environmental Services, 2008). Three were used in this incident: the Jerome© MVA, Lumex© 915+ and Lumex© RA-915-light. The Jerome© Mercury Vapor Analyzer (Jerome© MVA) is accurate only when mercury vapor concentrations are greater than 1,000 ng/m^3. Interferences to its accuracy include smoke, nitrogen and sulfide compounds. In order to sample ambient air at levels ≤ 300 ng/m^3, the Jerome© MVA could not be used. The Lumex© 915+ conducts real-time monitoring (one per second), data collection and data logging in real-time with storage capability to save separate files. It features an on-board display with a set point level alarm. Standard multi-path mode has levels of detection 2 – 20,000 ng/m^3. For higher concentrations, the single path mode can be employed with levels of detection 500 – 200,000 ng/m^3. N.B.: This 915+ instrument is not to be confused with Lumex RA-915-light which has levels of detection 100 – 100,000 ng/m^3. Both the Lumex© 915+ and RA-915-light have +/- 20% instrumentation bias. High humidity (greater than 95% at 35º C or 95º F) gives false positive readings. (OhioLumex, 2001.) Periodic readings with on/off cycling must be performed with and without the glass filter to check for mercury contamination of sampling tube itself. The glass filter must be replaced if the difference between these two readings is greater than 10%. Filter checks must be performed initially and after every four hours. The instruments' major limitation is the four-hour rechargeable battery that cannot be removed from unit for charging.

Initially at the time of the incident, there was one Jerome© MVA available to responders. Subsequent to the initial screening, a national call was issued which resulted in a number of Lumex© 915+ and Lumex© RA-915-light meters being located and shipped to Rhode Island for contractors to use during reconnaissance, remediation and re-occupancy. Lack of real-time equipment availability was a major obstacle to effort and efficiency.

Contract personnel reported that the Lumex meters only had 3.5 hours actual work time and the required recharge took eight hours during which the unit had to be turned off. Additionally, it was reported to have 10% estimated variability from unit to unit due to different sensitivities and drift.

Reconnaissance

The U.S. EPA Region 1 contractor conducted initial environmental monitoring. An initial assessment and clearance screening level (ACSL) of 3,000 ng/m^3 was used. These readings were taken in real-time using a Jerome© MVA. Three of the six buildings' common areas failed this criterion. 50% or more of the units in each building failed. (See Table Three.)

Real-Time Hg^0 Air Monitoring Data (ng/m^3)

On October 28th, RIDEM, U.S. EPA Region 1 and the EHEALTH agreed to an ACSL of 300 ng/m^3, the U.S. EPA inhalation reference concentration (RfC) for elemental mercury (U.S. EPA, 1999). Over three days, contractors conducted a detailed initial environmental assessment with direct reading mercury vapor analyzers. They measured each and every room with ten second average samples at each sample point at a minimum of one to three inches and three feet above the floor. Additional samples were taken of upholstered furniture, beds, closets, sink and tub/shower drains, and vacuum cleaners. In one building, four apartments had readings above 25,000 ng/m^3 requiring response personnel to wear personal protective equipment level C (air-purifying respirators with mercury vapor cartridges). Seven apartment units had levels within 20% instrumentation bias ($\geq$ 240 ng/m^3 to 300 ng/m^3). (See Table Four.)

Locations of Highest and Lowest Hg^0 Readings

Overall, the highest readings were found in apartment entryways (31/50) and the lowest in the bedrooms (34/52). Highest readings were generally found at floor level (34/50). (See Table Five.)

Relocation

All 140 residents were relocated. Some residents went to local hotels with the assistance of the local Red Cross; others stayed with relatives or friends. Seventy-six of the residents were women of whom 41% were of childbearing age (ages 16 to 49). Twenty-five percent were children under the age of sixteen. Though there is limited documentation of screening the residents themselves, there was no general mass decontamination prior to relocation. Most personal belongings passed a screening test before residents left the apartment complex. However, property and building access continued sporadically for eight days with many of the residents subsequently removing unscreened items from the property. This contributed significantly to secondary contamination of other sites.

Removal

Onsite Contractors

Contractors were hired by the gas company to perform reconnaissance, removal and replacement. There were inconsistencies with documentation, monitoring and remediation procedures across and among onsite contractors. Onsite worker safety/health was the responsibility of each individual contractor. Each contractor created and implemented their health and safety plan (HASP). While RIDEM met with contractors on a regular basis, there was no third party onsite safety and health professional ensuring that each contractor followed remediation and sampling guidelines according to their plans.

Decontamination Process

Remediation began with the least contaminated building. Concurrent remediation commenced in the most contaminated building. Over a three week period, contractors documented the contents of each apartment and identified mercury-impacted items. A scribe was paired with each worker to assist with this process. Subsequently, mercury-impacted items were cleaned using a decontaminating agent such as HgX© (Acton Technologies, 2008) and/or a special vacuum with a high efficiency (HEPA) filter such as the Mini-Merc© (Nilfisk, 2008). After each round of cleaning, the apartment was re-sampled in real-time for mercury vapor levels. Unfortunately, some remediated units were re-contaminated during the remediation of more heavily contaminated units, thus requiring additional rounds of decontamination.

Heating/Ventilation Cycles. Cycles of heating for eight hours at 80 to 85 degrees Fahrenheit or higher then reducing the heat to 70 degrees Fahrenheit and venting to the air for at least two hours were employed. At first, existing baseboard heating systems and open windows were used. However, these existing residential heating systems were unable to consistently maintain the required temperature for decontamination. For the most contaminated building, portable heaters and negative air scrubbers with activated carbon filters accelerated vapor removal. This process was extremely efficient and effective. Monitoring of the scrubber outlets assured exhaust mercury vapor concentrations did not exceed 300 ng/m^3.

Household and Personal Items. Household items that were not able to be decontaminated were refrigerator, sink/tub/shower drains, vacuums, mattresses, carpet. Personal items not able to be decontaminated included leather shoes, plastic toys, doormats/floormats. All frozen and refrigerated food and sink/tub/shower drains were disassembled and discarded automatically. Some items were taken off-site for additional decontamination. This offsite process involved bagging the personal items, heating them to 90 – 140 degrees Fahrenheit for 24-hours then ventilating them adequately before re-testing. Items that could not be adequately decontaminated to less than 1,000 ng/m^3 were disposed as household waste. Items with readings >10,000 ng/m^3 were disposed as hazardous waste. These items included carpet, tile flooring, garbage disposals, furnace filters, vacuum cleaners, mattresses, leather shoes, sneakers, clothes and plastic toys. In general, porous materials are difficult / impossible to decontaminate. One car was impounded and disposed as hazardous waste. All other mercury sources present in the home e.g. thermometers and thermostats were removed and replaced with electronic versions.

Structural Items. For the most contaminated building, disposed items included base moldings, plywood subfloors, baseboard heater covers, plumbing to the main drain stack, building entryway and concrete stairs.

Surrounding Property. All plantings, grass, top soil and pavement were removed and replaced.

Re-Occupancy

Within each building, post-heat measurements had to satisfy the screening protocol before clearance sampling was conducted, i.e., 90% of readings had to be less than 300 ng/m^3 and 100% less than 360 ng/m^3. This was to account for the direct-reading mercury vapor analyzer's ± 20% instrumentation bias. Graph One illustrates the average mercury levels taken after a second round of cleaning and after each round of heating/ventilation. While initial readings (post-clean #2) were below 300 ng/m^3, the readings after the first heat-vent cycle clearly shows the release of additional mercury vapor. In 43% of the units, mercury vapor levels increased post-heating over post-cleaning. Readings taken after the second heat-vent cycle were 100 ng/m^3 and lower with one exception.

EHEALTH established the residential occupancy level (ROL) at 1,000 ng/m^3. Using a modified NIOSH method 6009 (CDC NIOSH, 2004), eight hour time-weighted average (TWA) hopcalite air samples tested below 500 ng/m^3. Fifty-two percent were below the level of detection (200 ng/m^3). (See Table Six.) It was concluded that no further remediation was required. EHEALTH issued a clearance letter for site reconstruction to commence which was completed December 18th.

Prior to residential re-occupation, all personal belongings, vehicles and temporary housing were screened for mercury vapors. Several personal items exceeded the ACSL and were disposed with the owners' permission. One hundred thirty (130) sites in 15 cities and towns across RI and MA including 96 private residences, 23 institutions and 11 commercial properties were investigated. There was extensive secondary contamination. Two schools and four residences tested above the ACSL. School contamination was isolated from occupied areas. Residences were evacuated until remediation and reconstruction could be completed. By December 27th, all the residents had returned to their apartments.

Biological Monitoring

Eighty-nine residents (64%) submitted blood samples approximately *30 days* after estimated first exposure. Ten (11%) residents had total blood mercury levels (THg) $\geq$ 10 µg/l. A month later, six of those ten individuals submitted random urine samples. Four residents (57%) had urinary mercury levels (UHg) $\geq$ 10 µg/l. Non-residents associated with identified in-state and out-of-state mercury-impacted locations were tested for total blood mercury with no results exceeding 10 µg/l. One person had a urinary mercury level > 20 µg/l. Urine mercury levels were not creatinine corrected. (See Table Seven.) No other medical data were made available to EHEALTH. Individuals with mercury levels $\geq$ 10 µg/l were advised to follow-up with their healthcare provider.

The geometric mean and 95% total blood mercury concentrations for residents and non-residents who were tested are compared to the 2001 – 2002 National Health and Nutrition Examination Survey (CDC NCHS, 2009). (See Table Eight.) The geometric means for residents were 2.4 times higher on average than NHANES with resident children 2.8 times higher. Resident children were 4.8 times higher than non-resident children. Resident women of childbearing age were 2.1 times higher than non-residents. No conclusions can be drawn from these biological monitoring data.

Recommendations

Analysis of this response suggested that modifications to assessment and decontamination procedures would increase the efficiency and expediency of future responses to elemental mercury-related incidents.

Assessment and Decontamination Procedures

The following recommendations were made:

1. Establish immediately and continue to enforce strict perimeter security.
2. Set up designated walking paths to avoid walking in contaminated areas.

3. Conduct and document monitoring identically to facilitate comparison of subsequent measurements and to minimize transcription errors, especially when there are multiple contractors.
4. Where there is external contamination being brought into the residence (as opposed to the residence being the primary source of contamination), initially sample only the residential entry. If the entry is greater than or equal to ACSL, the residence fails. If the entry is less than ACSL sample each room.
5. Take only floor level readings during the initial assessment and remediation process to ascertain degree of contamination. (Take additional air samples in the breathing zone to assure adequate worker protection.)
6. Remove the following items *before* heating/venting cycles: wall-to-wall carpet, J/P traps, garbage disposals, vacuum cleaners, shoes, plastic toys and frozen and refrigerated food.
7. Remediate the *most* contaminated residences/rooms and all common areas *first* to minimize cross-contamination.
8. Employ two to three heating/venting cycles *first*, then identify remaining hot spots for decontamination/disposal. Use supplementary heaters with exhaust scrubbers.

State and Federal Response Guidelines

The following recommendations were made:

1. Require onsite Certified Industrial Hygienist (CIH) or a Certified Safety Professional (CSP) to oversee the safety/health aspects of remediation.
2. Establish a level of 300 ng/m^3 for the ACSL (real-time) and the ROL (eight-hour time-weighted average) for residences in order to provide a greater margin of safety. These lower levels are both measurable and reasonably achievable. However, this lower ROL would require modifying and validating NIOSH air sampling method 6009.
3. To conservatively account for the ± 20% error margin in direct reading instrumentation, require 90% of ACSL readings ≤ 240 ng/m^3 and 100% ≤ 300 ng/m^3.
4. EHEALTH should assess the need for clinical assessment and biological testing. Collect blood and urine samples simultaneously; analyze the blood for speciated mercury with urinary mercury creatinine corrected.
5. More NHANES data are needed on the entire U.S. population for urinary mercury. Currently, urinary mercury levels are tested in women of childbearing age only.
6. Non-residents had geometric mean total blood mercury levels less than comparable NHANES' levels. This was unexpected. It has been speculated that Rhode Islanders consume more fish than the U.S. population and thus would have higher blood levels. There is a need for state-specific biological and environmental background levels.

Evidence-Based Practice

This study's recommendations are based on the ALARA (As Low As Reasonably Achievable) Principle. Recommendations were matched to key findings. Data show that lower action levels are achievable with current remediation methods. Additionally, direct reading instrumentation with lower detection level is commercially available. Modification to NIOSH 6009 Method is possible as demonstrated but requires validation.

Challenges

The greatest challenges of responding to residential elemental mercury contamination lie in communicating risk to residents affected by a hazardous material spill. The importance of participatory discourse should be emphasized when establishing and/or modifying response policies and procedures.

Public Perception of Risk

Risk is defined as the probability of the occurrence of harm over some period of time (IRGC, 2005). Risk is also the distinction between reality and possibility (Renn, 1992). There are large discrepancies between scientists and the public in the way each defines, perceives and evaluates risks. For lay people, perception is reality. Lay people have biases in their abilities to draw inferences from probabilistic-based information. For them, contextual familiarity provides their frame of reference for decision-making. The perception of risk is highly influenced by socially and culturally-embedded values and beliefs (Rayner, S. 1992).

The concept of contamination is not an easy concept for the public to understand, particularly when there is an absence of sensory input. Even though beads of mercury may have been visible on the pavement of the apartment complex, there was no fire, no train nor truck wreck nor chemical plant emitting foul-smelling smoke. The initial incident had happened three weeks previously. The residents felt fine. Extended latency periods with long-term health implications are very difficult to comprehend in the short-term. The word “contaminated” in and of itself has moral implications. Something or someone that is contaminated is thought to be “unclean” or “polluted”. And the consequence of being “contaminated” is social isolation. (Douglas, M., & Wildavsky, A., 1982.) One must be very cognizant of how one refers to the people and/or their personal possessions in such a situation; using the phrase “mercury-free” would be preferred.

Over a period of a few days beginning with the most contaminated building, residents were told they would have to evacuate. They were given a choice to either stay with relatives and/or friends or they would be “put up” in a hotel until it was safe to return. The residents were not told how long they would be evacuated; most assumed it would be a few days. They were told their belongings that they were taking with them would have to be “screened” first. This turned out to be a very long and slow process. There were not enough monitors available for this purpose. There was a loud outcry of frustration at the process – a process that was not responsive to their needs.

The social amplification of the consequences of risk is defined by the cultural, social and individual structures and processes that shape the overall societal experience of risk. (See Table Nine.) The consequences of risk include those that are a result of direct harm and those that are associated with the social processing of the risk event. (Kasperson, R. E., 1992.) Since there was no perimeter security established initially, some residents left on own accord and many returned repeatedly during the first eight days to remove additional unscreened items. There was a general belief among those residents whose belongings’ were tested and found not to be contaminated, to assume that everything else they owned was also not contaminated.

Communicating Risk

Inconsistencies between ‘official’ sources of information confused the residents, making their comprehension of the risk involved even more difficult. One-way, carefully orchestrated and smartly-packaged messages did not persuade them either. In fact, they served only to further deepen public distrust of the gas company and, by association, the regulatory governmental agencies involved. There was public outrage. Distributional inequities of power, resources and social values became issues of trust, blame and accountability (Klinke, A., & Renn, O. 2002).

Risk communication must be an *ongoing, open and honest dialogue* where concerns of the public as relevant stakeholders are heard and addressed. Regularly scheduled meetings were held between the residents and representatives of the RIDEM and EHEALTH to address residents' concerns. The goal of these meetings was not only understanding and informed choice but to build a relationship of mutual trust and respect (IRGC, 2005).

Is it safe? According to the protocols established for this incident, within each building, post-heat measurements had to satisfy the screening protocol before clearance sampling was conducted, i.e., 90% of readings had to be less than 300 ng/m^3 and 100% less than 360 ng/m^3 to account for the direct-reading mercury vapor analyzer's ± 20% error margin. Subsequent to this screening, an eight-hour time-weighted average hopcalite air sample was taken. If that sample was below 300 ng/m^3, then the residents could return home safely.

Is it safe enough? Residents asked: "Why isn't the level zero?" By modifying both air sampling and analytical methods, the level of detection was lowered to 200 ng /m^3.

Is it right? "If mercury is so hazardous, why are you saying it is safe to return when there is mercury still in our apartments?"

These questions are the reason why there must be an equal blending of science and culture when establishing policy. *Sometimes science alone is just not enough.* The goals of risk communication are to resolve conflicts and find compatible solutions. There are large discrepancies between scientists and the public in the way each defines, perceives and evaluates risks. For lay people, perception *is* reality and their frame of reference for making decisions is contextual. (*Meaning* is as important as the numbers themselves). Risk-related issues are usually characterized as conflicts involving various levels of complexity, uncertainty and ambiguity. They require a balanced form of communication. The issues should be clearly identified and separated before implementing specific communication strategies to resolve them. (Klinke, A., & Renn, O. 2002.)

Update

This incident displaced 140 residents for three months and cost an estimated $6.6 million dollars. Ultimately, preventive efforts must emphasize corporate compliance and regulatory enforcement of existing environmental regulations with appropriate criminal and civil action against violators. "*On October 15, 2008, Southern Union was convicted by jury of knowingly storing liquid mercury without obtaining the proper permits in violation of federal law. Knowingly storing hazardous waste without a permit carries a maximum fine of $50,000 for each day of violation.*" (U.S. Department of Justice, 2008.) The company is appealing the verdict.

Acknowledgements

This study was funded by a grant from Rhode Island Department of Health, Office of Environmental Risk Assessment through Salve Regina University of Newport, Rhode Island. The author would like to thank the following individuals: Thomas E. Hamilton, CIH and President of OccuHealth, Inc. of Mansfield, MA and Robert Vanderslice, PhD, Toxicologist and Team Leader for Healthy Homes and Environment at the Rhode Island Department of Health for their expert assistance in preparing this article.

The timeline and environmental monitoring data in this report were compiled from a report by Burns and McDonnell Engineering Company, Inc. of Oak Brook, IL. The report is available free to the public at the Pawtucket, RI Public Library.

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Tables and Graphs

Table One: U.S. EPA Action Levels

Level	**Mercury** **(concentration measured in air)**	**Response**
1	≥ 10,000 ng/m^3 (Real-time)	Relocate residents immediately
2	> 1,000 ng/m^3 to < 10,000 ng/m^3	Schedule relocation as soon as possible
3	≤ 1,000 ng/m^3 (8-hr. TWA)	No action necessary

Source: U.S. EPA Region 5, 2001, p. 3-13

Table Two: U.S. EPA Action Levels for Mercury Concentrations Measured in Soil

Land Use	**Mercury Action Levels** (concentration measured in soil)
Residential	16 mg/kg

Commercial	250 mg/kg
Industrial	230 mg/kg

Source: U.S. EPA Region 5, 2001, p. 5-11

Table Three: Percentage of Units That Failed Initial ACSL

Building	**% Units Failed ACSL (> 3,000 ng/m^3)**
1	50%
2	100%
3	92%
4	67%
5	83%
6	100%

Table Four: Highest Mercury Vapor Readings (ng/m^3) from Initial Site Assessment by Unit and Building

Hg^0 (ng/m^3)	**Bldg 1**	**2**	**3**	**4**	**5**	**6**
Building Entry	**297**	4,438	88	1,570	159	1,626
Boiler Room	114	627	1,020	1,522	NA	NA
Unit 1	372	2,357	1,648	793	74	2,760
2	**295**	5478	797	392	7,420	
3	224	504	4973	**286**	1,373	
4	200	1820	**276**	**294**	525	

5	543	13,090	2,939	230	342	
6	303	**28,830**	1,649	446	671	
7	1,557	2,454	626	**299**		
8	354	**28,000**	323	487		
9	253	5783	729	864		
10	**295**	**28,337**	810	399		
11	**256**	**28,830**	2,748	1,790		
12	2540	3770	620	2081		

Table Five: Number of highest and lowest readings of mercury vapor by specific location and sampling level within each unit

	Entry	**Kitchen**	**Living**	**Master**	**Bedrm**	**Bath**	**Floor**	**Waist**	**Breathing**
Highest	**31**	3	7	0	4	5	**34**	9	7
Lowest	3	7	5	19	15	3	-	-	-

Graph One: Mercury Vapor Averaged Readings Post-Clean and Post-Heat Cycles

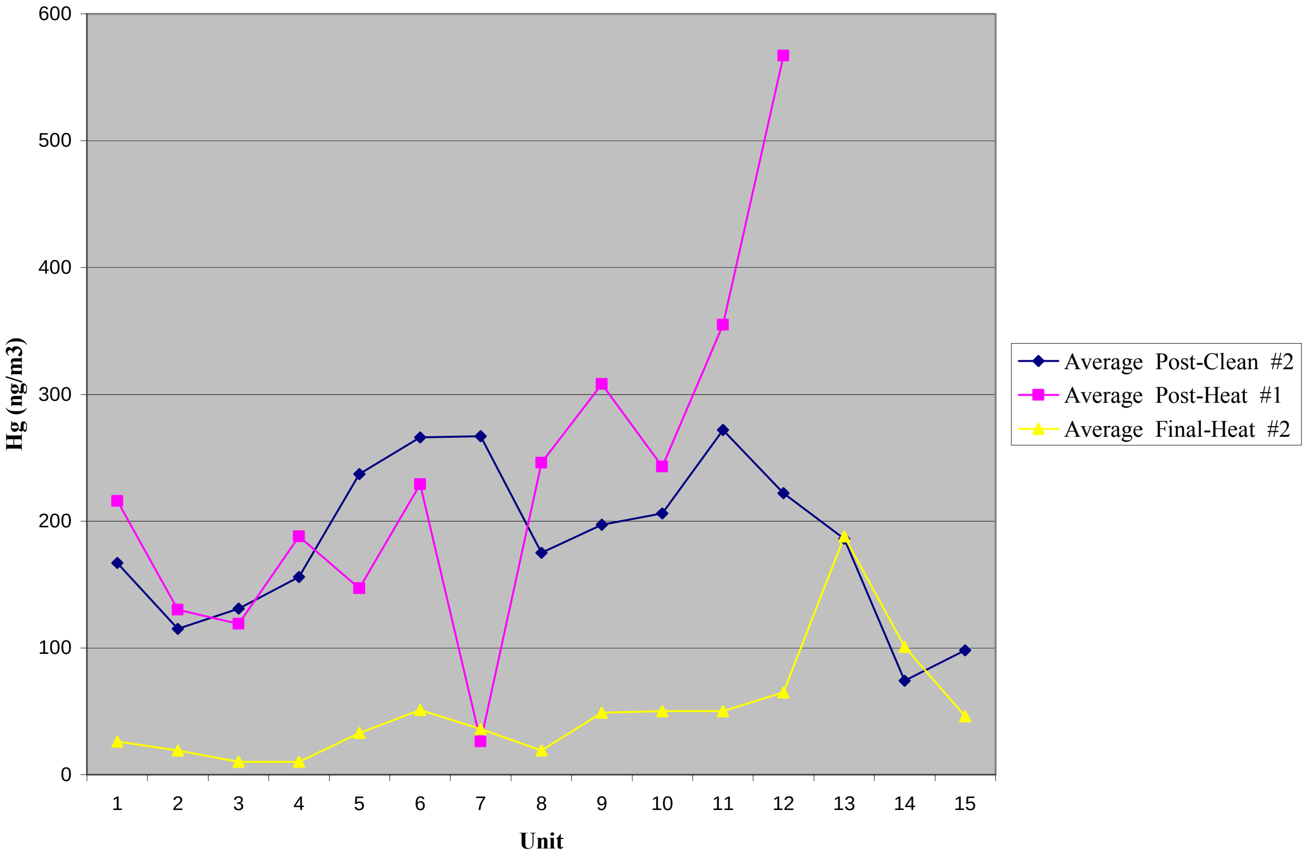

Table Six: Distribution of Hopcalite Clearance Sampling Results (8-hour TWA) in Building Entries and Units

Hg^0 (ng/m^3)	**< 200**	**200 - 499**	**500**
Entries	4	1	0
Units	**28**	14	12

Table Seven: Distribution of Biological Monitoring Data

HgB (µg/l)	**< 1**	**1 - 4**	**5 - 9**	**10 - 14**	**15 – 19**	**≥ 20**
Residents	22	47	10	4	6	0
Non-Residents	34	56	1	0	0	0

HgU (µg/l)	**< 1**	**1 - 4**	**5 - 9**	**10 - 14**	**15 – 19**	**≥ 20**
Residents	1	1	0	2	1	1
Non-Residents	0	0	0	0	0	1

Table Eight: Mercury Levels in Blood (HgB) and Urine (HgU) in Residents and Non-Residents as Compared to NHANES (2001 – 2002)

	Residents		**Non-Residents**		**NHANES (2001 – 2002)**	
HgB (µg/l)	**Geometric Mean**	**95th Percentile**	**Geometric Mean**	**95th Percentile**	**Geometric Mean**	**95th Percentile**
Children (ages 1 – 5)	0.905 (0.000 – 2.944)	2.944	0.189 (0.000 – 1.386)	1.386	0.318 (0.266 – 0.377)	2.3 (1.20 – 3.50)
Females (all ages)	0.840 (0.000 – 2.639)	2.433 (2.433 – 2.639)	0.342 (0.000 – 1.946)	1.386 (1.386 – 1.946)	0.329 (0.265 – 0.407)	2.6 (1.30 – 4.90)
Females (ages 16 – 49)	0.845 (0.000 – 2.639)	2.554 (2.554 – 2.639)	0.399 (0.000 – 1.946)	1.554 (1.554 – 1.946)	0.833 (0.738 – 0.940)	4.6 (3.70 – 5.90)
Males (all ages)	0.984 (0.000 – 2.944)	2.944	0.306 (0.000 – 1.386)	1.386	0.307 (0.236 – 0.369)	1.7 (1.40 – 2.00)
HgU (µg/l)	**Geometric Mean**	**95th Percentile**	**Geometric Mean**	**95th Percentile**	**Geometric Mean**	**95th Percentile**
Females (ages 16 – 49)	1.152 (0.000 – 2.303)	2.303	0.606 (0.553 – 0.665)	3.99 (3.50 – 4.63)	NA	NA

Source of NHANES Data: CDC NCHS (2009)

Table Nine: Risk-Related Characteristics that Contribute to Public Outrage

Less Outrage (More Safe)	**More Outrage (Less Safe)**
Voluntary	Involuntary or Coerced
Natural	Industrial or Anthropogenic
Familiar	Unfamiliar/Exotic
Not Memorable	Memorable
Not Dreaded	Dreaded
Chronic	Catastrophic
Knowable (Detectable)	Unknowable (Not Detectable)
Controlled by the Individual	Controlled by Others
Fair	Unfair
Morally Irrelevant	Morally Relevant
Trustworthy Sources	Untrustworthy Sources
Responsive Process	Unresponsive Process

Source: Sandman (1993)