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Concentrations of Gaseous Elemental Mercury in Ambient Air within an Academic Chemistry Building

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Abstract Gaseous elemental mercury (GEM) concentrations were determined within an academic chemistry building by cold vapor atomic fluorescence spectrometry. Concentrations varied depending on the room activity, with night time and weekend levels the lowest and most stable (typically between 10 and 20 ng/m^3), and daytime weekday levels the highest (averaging about 3–5 times higher). Laboratory air exhibited daytime concentration spikes as high as 1,600 ng/m^3. Office levels were similar to weekend laboratory concentrations, suggesting a general building-wide mercury background. However, concentration spikes suggest GEM levels may be exacerbated by foot traffic which may cause motion-induced wafting from higher concentration areas. Based on current regulations the GEM levels do not present a health hazard.

Keywords Mercury · Gaseous elemental mercury · Cold vapor · Atomic fluorescence spectrometry · Indoor air

For decades elemental mercury has been widely used in academic chemistry laboratories for a variety of purposes, most notably barometers, thermometers, electrical switches, and atomic line lamps. The element is the only metal that is a liquid at standard conditions (0°C, 100 kPa). It is also dense (13.55 g/mL at 20°C) and has a relatively high vapor pressure (0.17 Pa at 20°C) (CRC 2007). Other useful properties include a capability to conduct electricity and to form an amalgam with gold.

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It is well known that mercury is a heavy metal pollutant that can damage the central nervous system, affecting the brain and causing developmental disorders in children. Exposure to elemental mercury vapor occurs primarily by direct transport across the lungs where it can enter the blood stream and be distributed throughout the body, including the brain; the respiratory and toxicological consequences of mercury vapor are detailed elsewhere (Lien et al. 1983). Possible symptoms from a large acute exposure include nausea, vomiting, abdominal pain, kidney damage, and death. Potential symptoms from a chronic exposure include inflammation of the mouth and gums, kidney damage, muscle tremors, spasms of the extremities, personality changes, depression, irritability, and nervousness (OSHA 1991). Due to its high vapor pressure, even small amounts of metallic mercury released into unventilated areas can raise air concentrations to harmful levels. The current environmental and occupational health standards (risk assessment and action levels) for mercury vapor are summarized in Table 1.

Whereas many colleges and universities are moving away from using the toxic element, undoubtedly the liquid metal has been spilled inside laboratories over the years, especially in general chemistry laboratories where thermometers are routinely broken. As a liquid, the metal will pool in low areas and may be hidden or difficult to access (e.g., in drains, underneath tiles, floor cracks, etc.), thus some of the element may be left behind even after "cleanup" procedures are used. Also, old latex paint can contain high levels of mercury and expel gaseous mercury (Beusterien et al. 1991).

Gaseous elemental mercury as an indoor air pollutant has been the subject of a number of studies (e.g., Smart 1986; Carpi and Chen 2001; Riley et al. 2001; Liu et al. 2009). After fish consumption indoor air may be the next

Table 1 Environmental and occupational health standards for mercury vapor

Agency	Concentration (ng/m^3)
OSHA ceiling exposure limit[a]	100,000
NIOSH recommended exposure limit[b]	50,000
ACGIH threshold limit value[b]	25,000
EPA reference concentration[c]	300
ATSDR minimal risk level[d]	200

[a] The concentration can not exceed this value at any time

[b] Time-weighted average for an 8 h day

[c] Used primarily as a screening tool; adverse health effects do not necessarily result from exposure at or near these levels

[d] Estimate of daily exposure which is to be without appreciable risk of adverse heath effects

OSHA Occupational Safety and Health Administration, *NIOSH* National Institute for Occupational Safety and Health, *ACGIH* American Conference of Governmental Industrial Hygienists, *ATSDR* Agency for Toxic Substances and Disease Registry, *EPA* US Environmental Protection Agency

biggest source of mercury exposure (Carpi and Chen 2001). Occupations which handle mercury (e.g., dental and gold trade shops that prepare or heat amalgams containing mercury) have much higher ambient air mercury concentrations than residential houses (Stone et al. 2007; Bastos et al. 2004).

In this study, we measured gaseous elemental mercury (GEM) in several laboratories and an office located in the Department of Chemistry and Biochemistry at the University of Mississippi. The building was first occupied in 1977 and has recently undergone an extensive renovation, including its ventilation system. The purpose of the study was to monitor GEM in the ambient air within the building under various use scenarios. Levels were compared to occupational safety permissible and recommended exposure limits.

Materials and Methods

A mercury vapor analyzer based on cold vapor atomic fluorescence spectrometry (CVAFS) was used to measure GEM (Model 2537B; Tekran Inc., Toronto, Canada). A flow diagram for the system is shown in Fig. 1. Air was sampled through a Teflon inlet tube which was placed about 1.5 m above the ground, at about the breathing zone of a typical standing adult. The automated system employs dual gold traps which effectively remove (capture) elemental mercury vapor from ambient air pulled through the cartridges. The instrument cycles such that while one gold cartridge is capturing (pre-concentrating) mercury, the other is rapidly heated, desorbing its captured mercury. The released mercury is then carried by a flow of ultra-high purity argon into a fluorescence cell for measurement. Inside the cell, atomic mercury is excited by 253.7 nm photons emitted from a sealed mercury lamp. As the excited mercury atoms relax back to the ground state, light of the same wavelength is re-emitted, some of which is detected by a photomultiplier tube situated at 90° to the excitation source. The combination of a low background and the detector's high amplification yields one of the most sensitive analytical techniques for mercury. The automated dual trap system allows GEM readings every 5 min and unattended operation for extended periods (weeks). Additional details of the instrument can be obtained from the manufacturer.

In this study, the instrument was calibrated nightly using an internal permeation source. There was good agreement between calibration peak areas for the two cartridges; the average relative difference was 0.6%. Instrument sensitivity was high, averaging 2.3 mV per picogram of Hg. Blank levels (measured daily using a canister that scrubs mercury from the air) were negligible, averaging less than 3% of the minimum GEM levels found for that day. As noted earlier, the instrument uses two gold cartridges which yield alternating data points. This provides the advantage of comparing the average of the two concentration values over long periods of stable concentration to check for trap bias that may be caused by passivation or leaks. This is important because some laboratories may have very high levels of acid and/or organic vapors present that may passivate the pure-gold cartridges over an extended period of time, depending on the concentrations levels. For this experiment, gold cartridge passivation was not observed (A/B cartridge bias was less than 1%, $n = 35$; data from a stable overnight period). Moreover, we used a relatively small sample volume (7.5 L) and a short monitoring time period (5 min). The cartridges are also heated slightly

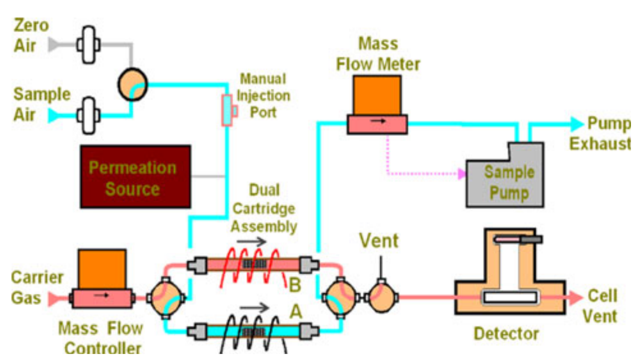

Fig. 1 Flow diagram for the 2537 mercury analyzer. Used with permission from Tekran Inc. *Zero air* is mercury free air (i.e., air scrubbed of mercury) used for various purposes including flushing of system. The permeation source is a sealed internal mercury source which is used to periodically to calibrate the instrument. Other details of the instrument are available from the manufacturer

during collection to minimize adsorption of organic molecules. A detection limit of 0.2 ng/m^3 was estimated by repeated analysis of a low level standard and using the volume of air in a typical analysis.

Results and Discussion

The concentrations of GEM varied with the room type (i.e., purpose) and usage (i.e., occupancy). This is shown in Figs. 2 and 3. Each data point in the plots corresponds to a 5 min integrated average. Mercury concentrations ranged from 9 to 1,600 ng/m^3 and averaged 66 ng/m^3. This is comparable to an indoor air study that found an average of 69 ng/m^3 of mercury at 12 different sites chosen to represent a cross section of building types (Carpi and Chen 2001).

In this study, despite numerous potential sources of mercury with the building, the levels (in all cases) were below the permissible and recommended exposure limits defined by OSHA, NIOSH and ACGIH (see introduction). Also, given the short duration of the concentration spikes, the levels would not exceed the ATSDR minimum risk level even when focusing only on daytime hours. This may be partly due to continuous air exchange (turnover) within the building from operation of a large number of fume hoods; the building's ventilation system was recently overhauled from re-use to single pass air.

The highest concentrations were found for a common area that is located between four laboratories (Fig. 2). It is noteworthy that this area is smaller than the labs and does not have a fume hood. Spikes in the concentration of GEM, the highest of which reached 1,600 ng/m^3, corresponded to activity in the adjacent room (e.g., morning and afternoon lab sessions); doors are kept open between these rooms. There was no laboratory session on Friday and the concentration returned to an apparent background level of $<$50 ng/m^3. It is suspected that disturbances to air flow patterns (turbulence) in the room during class sessions from foot traffic redistributes mercury vapor from areas or pockets containing relatively higher levels, presumably in proximity to mercury sources, to the larger room volume. Scuffing of dust from the floor by foot traffic should not be an issue as it is filtered out prior to analysis. Humans can also be sources of mercury vapor, especially those with tooth fillings containing mercury amalgams. Cosmetics can also contain mercury (MMWR 1996). However, if humans were the only source of mercury, one might expect the room to gradually increase as mercury is exhaled or effluxed rather than exhibit large and inconsistent spikes in concentration with time.

Figure 3 corresponds to an instrumental laboratory. Again, there is a clear difference between concentrations

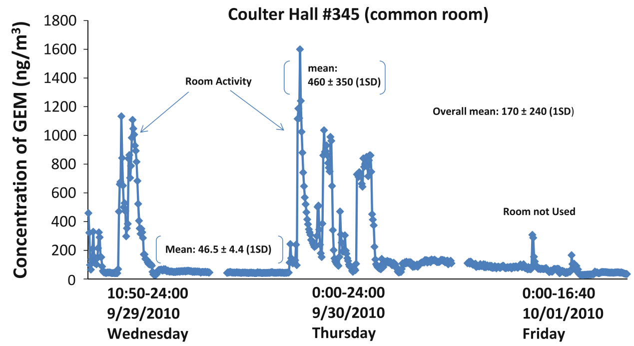

Fig. 2 Temporal fluctuations in gaseous elemental mercury in a common room between general chemistry laboratories. Each *data point* corresponds to a 5 min integrated concentration. The *gaps* in the *baseline* are inserted to delineate individual days. *SD* standard deviation

during the day, when the room is being used, and during the night, when activity ceases. The figure also shows that the weekend achieves a steady background state (16.7 $\pm$ 1.9 ng/m^3), significantly below the work-week daytime concentrations (64 $\pm$ 32 ng/m^3).

GEM in a faculty office adjacent to the general chemistry laboratories was similar to levels found in the laboratories weekends (date not shown). As noted, the building's ventilation system was recently overhauled. It plausible that there is a consistent ambient background level similar throughout the building, which can be exacerbated in areas by wafting from additional mercury sources resulting in the observed concentration spikes.

In summary, this study shows that the concentration of mercury in ambient air within a chemistry building fluctuates during the day depending on room activity and usage. Whereas GEM levels are significantly higher than outdoor air, the concentrations did not exceed the permissible and recommended exposure limits.

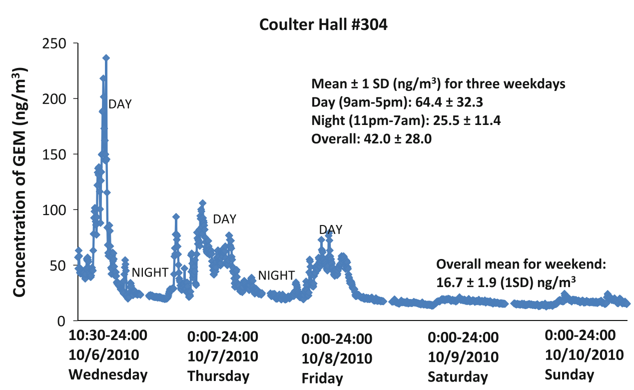

Fig. 3 Gaseous elemental mercury in a laboratory over the course of five days. Note the relatively low and stable concentrations during the weekend. The *gaps* in the *baseline* are inserted to delineate individual days. *SD* standard deviation

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