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Source, concentration, and distribution of elemental mercury in the atmosphere in Toronto, Canada

Elaine Cairns [a], Kavitharan Tharumakulasingam [a], Makshoof Athar [b], Muhammad Yousaf [a], Irene Cheng [a], Y. Huang [a], Julia Lu [a,*], Dave Yap [c]

[a] Department of Chemistry and Biology, Ryerson University, 350 Victoria Street, Toronto, ON M5B 2K3, Canada
[b] Institute of Chemistry, University of the Punjab, Lahore, Pakistan
[c] Ontario Ministry of the Environment, 125 Resources Road, Toronto, ON M9P 3V6, Canada

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ABSTRACT

Atmospheric gaseous elemental mercury [GEM] at 1.8, 4, and 59 m above ground, in parking lots, and in indoor and outdoor air was measured in Toronto City, Canada from May 2008–July 2009. The average GEM value at 1.8 m was 1.89 ± 0.62 ng m^{-3}. The GEM values increased with elevation. The average GEM in underground parking lots ranged from 1.37 to 7.86 ng m^{-3} and was higher than those observed from the surface parking lots. The GEM in the indoor air ranged from 1.21 to 28.50 ng m^{-3}, was higher in the laboratories than in the offices, and was much higher than that in the outdoor air. All these indicate that buildings serve as sources of mercury to the urban atmosphere. More studies are needed to estimate the contribution of urban areas to the atmospheric mercury budget and the impact of indoor air on outdoor air quality and human health.

1. Introduction

Mercury (Hg) is a highly toxic element (Sarikaya et al., 2010). It can be emitted from natural and anthropogenic sources, largely as gaseous elemental mercury (GEM) (Bagnato et al., 2009; Song et al., 2009; Goodarzi, 2004). The atmosphere receives most of the mercury emitted from these sources (Goodarzi, 2004). Elemental Hg has an atmospheric lifetime of around one year (Schroeder and Munthe, 1998), thus its effects are not limited to the areas where Hg is emitted. High levels of Hg have been observed in remote regions far from anthropogenic sources (Fitzgerald et al., 1998).

Due to its unique physical and chemical properties, Hg has been widely used in industry (e.g., in electrical equipment and control devices, in the electrolytic preparation of chlorine and alkalis), in agriculture (e.g., as pesticides, fungicides, and bactericides), in dental practices, in pharmaceuticals, and in daily products such as thermometers, barometers, bulbs, batteries, paints, and cosmetics etc. All the above-listed processes and uses are concentrated in cities. They, therefore in turn, are sources of mercury to the environment. Limited studies have indeed shown higher atmospheric mercury in urban areas (Witt et al., 2010; St. Denis et al., 2006; Carpi and Chen, 2002; Liu et al., 2002), and the concentrations of GEM in urban atmosphere varied with variation of urban structure and height (Song et al., 2009; St. Denis et al., 2006; Carpi and Chen, 2002). Our study (Cheng et al., 2009) showed that local sources which have neither been identified nor been reported in the Canadian National Pollutant Release Inventory (NPRI) might have contributed to the high levels of atmospheric Hg in Toronto. More studies are needed to identify the sources and distribution of elemental mercury in urban atmosphere and to estimate the contribution of urban areas to atmospheric mercury budget.

2. Experimental

2.1. Experimental location

All the experiments were carried out in the City of Toronto (population 2.5 million), Ontario, Canada, Fig. 1. According to the NPRI (Environment Canada, 2004), there is no source of Hg (cut-off level of 5 kg) in the city area.

2.2. Instrumental

Atmospheric GEM was monitored along the major streets, highways, at surface and underground parking lots in the city, using mercury vapor analyzer (Model 2537A, Tekran Inc., Toronto, Canada). The analyzer has a built-in air pump for air

* Corresponding author
E-mail address: julialu@ryerson.ca (J. Lu).

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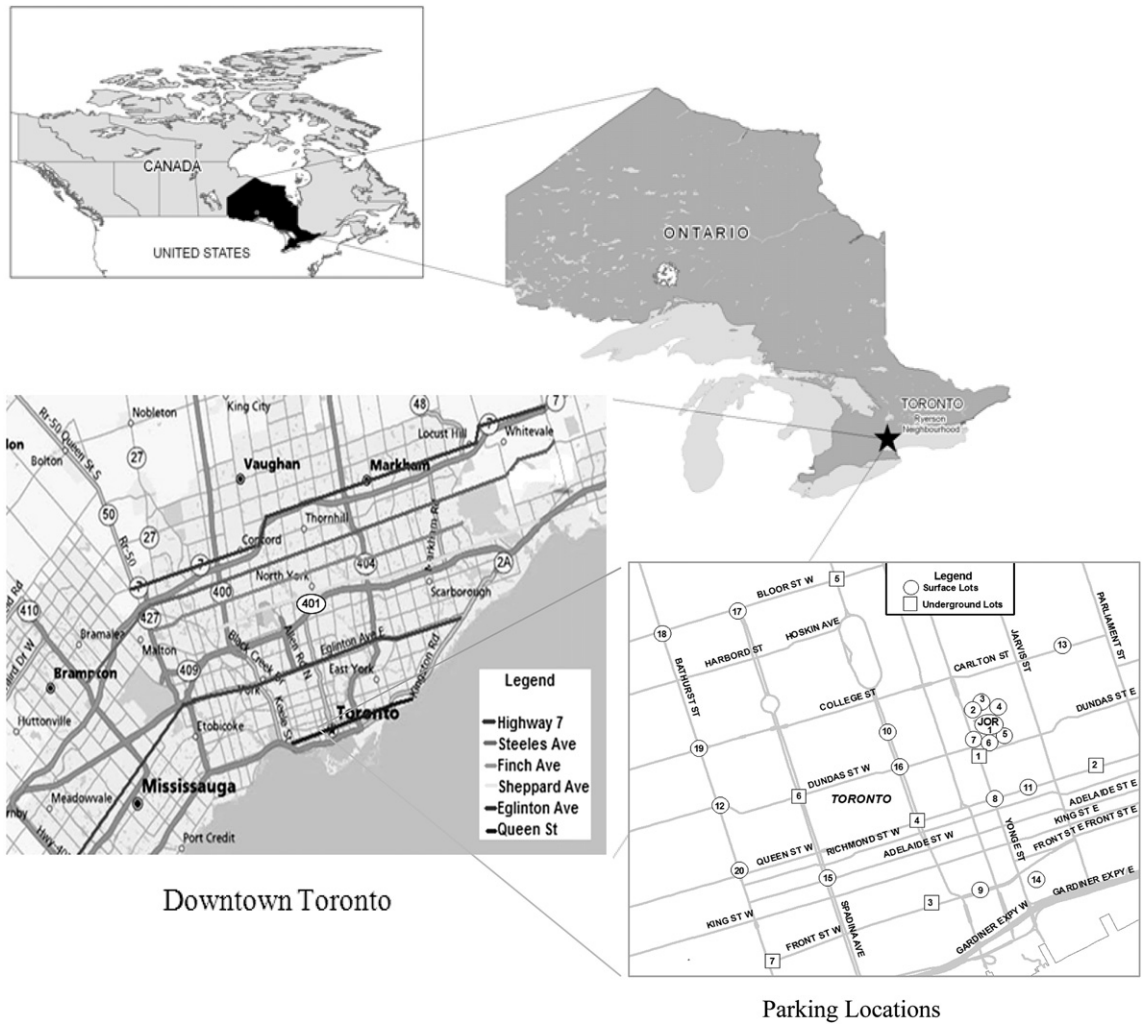

Fig. 1. Experimental locations.

sampling and employs dual gold cartridges, arranged in parallel, for Hg pre-concentration thus allowing continuous measurements of mercury in the air samples. After every 2.5 min pre-concentration period, mercury is thermally desorbed from the gold cartridges and determined using cold vapor atomic fluorescence spectrometry (CVAFS). Since the particulate matter in the air stream was removed by a front-end Teflon filter before it entered the analyzer, it is widely accepted that the analyzer measures GEM in the air sample. The analyzer was calibrated automatically through a built-in permeation mercury source every 23 h. The permeation mercury source was verified by manual injection before and after the field campaign. The internal permeation source provided approximately 1 pg s^{-1} of gaseous elemental mercury (Hg^0) at 50 °C into a zero air stream, whereas the manual calibration was done by injecting a certain volume of air saturated with mercury vapor at a known temperature from a mercury vapour calibration unit (Tekran Inc., model 2505, Toronto). The average detection limit was about 0.1 ng m^{-3} for GEM.

2.3. Experimental

During the street monitoring period, the analyzer was installed on board of a minivan with two inlets: one was hanging over the dashboard glass using a pole that was held on the rooftop of the van and was about 1.8 m above ground (i.e., at pedestrian level); the other was attached to a pole that extended about 4 m above ground. While driving along the streets and highways and parking underground, only the 1.8 m-inlet was used. A global positioning system (GPS) was used to track the locations of the analyzer. While parked at some of the surface lots, air was sampled from the two inlets in an alternative fashion. A second mercury analyzer, which was a part of the mercury speciation monitoring system, was running on the rooftop of Jorgensen Hall (JOR), Fig. 1, which is ~59 m above ground. Accordingly, while the van was parked around JOR, GEM was measured from three levels: 1.8 m, 4 m, and 59 m above ground.

Five rooms with different usage types were selected for the measurements of GEM in indoor and outdoor air. These rooms are located in the north and east sides of a square-shaped building (Kerr Hall, ~160 m long) with a courtyard in the middle: Room 1, a research laboratory on the 2nd-floor with windows facing east to a street; Room 2, an office on the 1st-floor with windows facing west to the courtyard; Room 3, a research laboratory on the 3rd-floor with windows facing south to the courtyard; Room 4, an office on the 3rd-floor with windows facing south to the courtyard; and Room 5, an undergraduate laboratory on the 2nd-floor with windows facing north to a street. During the experiments, the pump in the analyzer pulled air in from inside and outside (using Teflon tubing through a window, ~1.5 m away from the wall) in an alternative order for each room tested.

3. Results and discussion

3.1. Driving measurements

Fig. 2 presents the measured GEM concentrations along the major highways and streets in the City of Toronto. Measurements made on different days are marked as sample 1 to sample 6 and presented in the maps in Fig. 2 using different colors. The red bars indicate the GEM values > 3 ng m^{-3}, which was the average GEM reported by St. Denis et al. (2006) for June 20-Sept. 19, 2001 for downtown Toronto. The data were sorted and plotted for daytime (7:00–19:00, Fig. 2a), nighttime (19:00–7:00, Fig. 2b), non-rush-hour (19:00–7:00 and 11:00–16:00, Fig. 2c), rushhour (7:00–11:00 and 16:00–19:00, Fig. 2d), weekday (Fig. 2e), and weekend (Fig. 2f).