THE TEMPORAL DISTRIBUTION CHARACTERISTICS OF ATMOSPHERIC MERCURY IN AN URBAN AREA OF SEOUL, KOREA

Min-Young Kim[1], Z.-H. Shon[2], Ki-Hyun Kim[3], Young S. Yoo[4]

[1]Seoul Metropolitan Research Institute of Public Health and Environment, Seoul, 137-730 Korea, mykim5@seoul.go.kr; [2]Department of Environmental Engineering, Dong-Eui University, 995 Eomgwangno, Busanjin-Gu, Busan, 614-714 Korea; [3]Dept. of Earth & Environmental Sciences, Sejong University, Seoul, 143-747 Korea; [4]Dept. of Environmental Sysytem Engineering, Seoul Health College

ABSTRACT

In this work, the present concentration levels of gaseous elemental mercury (GEM) in Seoul, Korea are examined based on continuous measurements made over a long-term period of 1997 through 2002. The mean hourly concentration of Hg determined from this six-year period was computed to be 5.32$\pm$3.53 ng m^{-3} (N=27,170). The inspection of the diurnal distribution patterns indicated the presence of notably high concentration levels during nighttime relative to daytime (e.g., the mean hourly value as high as 9 ng m^{-3} in winter nighttime). When divided seasonally, the highest mean of 6.12 ng m^{-3} was also observed during winter followed by spring, fall, and summer. The results of our analysis confirmed the relative dominance of winter (seasonally) or nighttime (diurnally), while exhibiting a complicated trend on a long-term basis. Examination of our data over a different temporal scale consistently indicated that dynamic changes in Hg concentrations occurred through time in line with changes in the strength and diversity of the source processes. It is thus acknowledged that the presence of unusually high Hg levels is the consequence of intense man-made activities, while such signatures can vary in a competitive manner. Finally, the current status of Hg pollution in the atmosphere of three East Asian countries, China, Japan, and Korea, was assessed based on our measurements and literature review; the results indicated a highly complicated pattern in which the distribution of Hg is characterized by the presence of unusually high concentrations in concert with wide spatial variabilities.

INTRODECTION

The atmospheric pollution of mercury (Hg) has been officially documented since the mercury amalgamation process (e.g., patio) was practiced in ancient times (e.g., Blanchard, 1980). In fact, the consumption of Hg from mining activities for gold and silver ores was known to account for the major fraction of global Hg emissions in past

centuries. This type of source process is still crucial in certain regions of the globe (e.g., Central and South America: Artaxo et al., 2000), while the nature of the source processes is highly diverse in many industrialized countries and regions (e.g., Kim and Kim, 2002). Investigation of Hg temporal trends indicates a decrease in its concentration levels in certain regions of the globe; this may possibly reflect the fact that its pollution is controllable by the combined effects of several factors such as administrative regulations and advances in control technology (e.g., Slemr and Scheel, 1998). However, the gross trend of Hg is believed to increase largely due to the contribution of rapidly industrializing regions on the globe like China in East Asia (Pirrone et al., 1996).

In this work, we attempted to investigate the temporal distribution characteristics of Hg based on our long-term measurements made from a monitoring station located in the Yang Jae district of Seoul between 1997 and 2002. Through compilation of these long-term data sets, we attempted to analyze the behavior and distribution patterns of Hg from various respects. As we conducted a similar type of research using the data sets collected for a considerably more limited time period between 1999 and 2001 (Kim and Kim, 2001), the results of our present analysis over this 7 year period may be used to provide more representative figures of Hg behavior in an urban area of the far east Asia.

MATERIALS and METHODS

The atmospheric concentrations of gaseous elemental mercury (GEM: referred hereafter as Hg, unless otherwise specified) were determined from the Yang Jae district of Seoul, Korea for the period covering September 1997 through June 2002. The collection and analysis of Hg samples were made routinely using an on-line analytical system at our monitoring station located at the Seoul Metropolitan Research Institute of Public Health and Environment (SIHE). The general characteristics and all the relevant information of the study site and the surrounding area have been described previously (Kim and Kim, 1999). The site is a dense residential area surrounded by several public parks without any major stationary sources of anthropogenic origin.

In the course of the present study, we attempted to analyze and to describe the fundamental aspects of Hg behavior over varying time scale such as diurnally, seasonally, and annually. The concentrations of Hg were measured at every hour for the whole study period from the third floor laboratory of SIHE. The hourly Hg concentration data were measured by transferring outdoor air via 2 m long sampling train made of Teflon tubing (30 cm diameter) into an on-line automatic Hg analyzer

(AM-2 model, the Nippon Instrument Co., Japan); this system is well-known for its internally combined sampling/detection device. The precision of individual analytical systems, if evaluated in terms of relative standard error (RSE=meanx100/SE) of 5 replicate injection data of vapor-phase standards (at three different concentration levels of 1, 2, and 3 ng), generally fell in the range of 0.3~0.6 %. It should be noted that accuracy can be considered to be an important parameter to define the characteristics of the analytical system. However, we are not able to assess it directly owing to the unavailability of certified vapor standards. Hence, as an indirect means to overcome this limitation, the system was calibrated against several NBS standards (e.g., NBS-1632a, 1568, and 1575); the results revealed the values of mean accuracy in the 3~5 % range.

RESULTS and DISCUSSION

During the whole study period, our measurements of Hg were made basically on a routine basis except for certain periods; in fact, interruptions were frequent due either to instrumental problems or to the employment of the analytical systems for other study purposes (e.g., gradient measurements using two individual systems) (Kim and Kim, 1999; Kim et al., 2002, 2003). The longest period for which we failed to retrieve the data include one between spring 1988 and spring 1999**.** Except for such period, we were able to collect a total of 27,170 individual data points from the whole study period. Figure 1 depicts the temporal distribution patterns of Hg using its daily mean values. In Table 1, a statistical summary of the Hg measurement data and all the relevant environmental parameters collected for the whole study period is presented.

The presence of significantly high Hg levels was commonly found in Seoul during the late 80s (Kim and Kim, 2000) as well as in many Chinese areas at the present time (i.e., rapidly industrialized regions: Tan et al., 2000). The occurrences of those unusually high Hg values have hence been ascribed to strong man-made activities such as the use of anthracite coal. Despite the significant reduction in Hg levels (i.e., near 5 ng m^{-3}) relative to those previous time band, the present time Hg levels in our study site are still clearly distinguished not only from those measured in moderately urbanized regions of the Western countries but also from relatively clean areas in Korea. For instance, Nadim et al. (2001), after measuring Hg from 8 different locations of Connecticut, USA for a three-year time span, reported its grand mean concentration to be 2.06 ng m^{-3}. They observed the highest mean concentration of 3.76 ng m^{-3} from a highly populated inland site of Waterbury; but the mean concentration levels of most areas were approximately 50 % lower than those values**.**

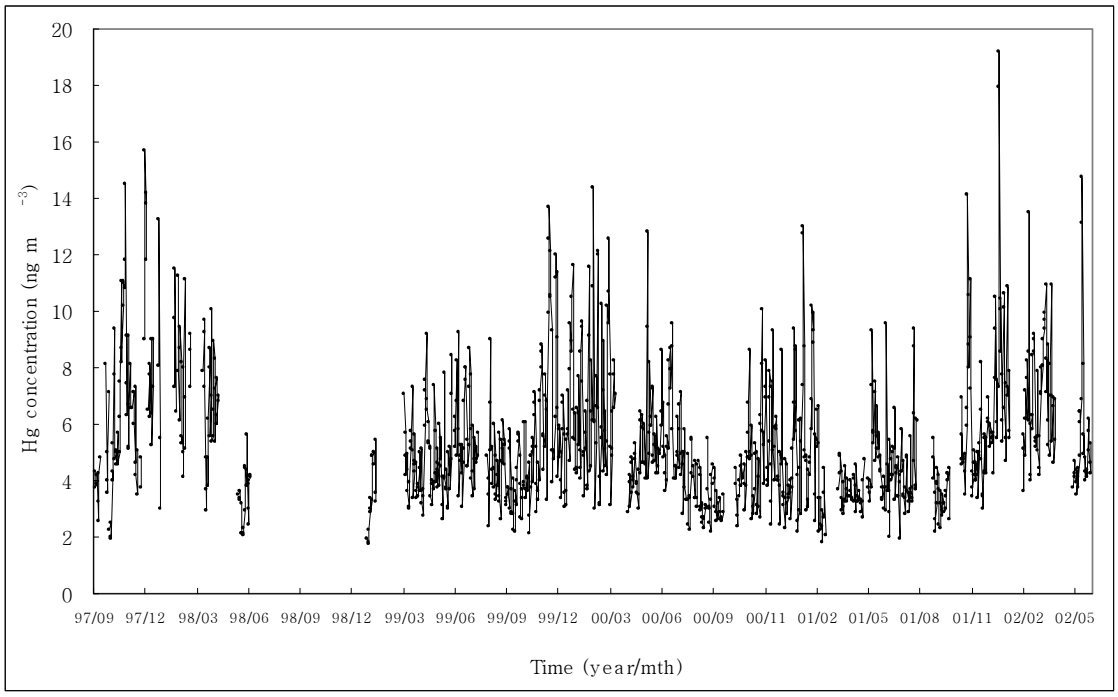

Fig. 1 A plot of day-to-day variabilities of Hg in Yang Jae district of Seoul, Korea during the whole study period between Sep. 1997 and June 2002.

	Hg (ng m^{-3})	**Temp.** (℃)	**UV** (MJ m^{-2})	**RH** (%)	**Wspeed** (m s^{-1})	**SO_2** (ppb)	**NO** (ppb)	**NO_2** (ppb)
Mean±SD	5.32±3.53	12.8±10.2	26.0±50.7	62.2±20.0	1.37±0.86	5.62±3.31	42.9±57.6	39.9±18.1
Range	0.03~118	-25.9~35.0	0.00~656	0.00~6.70	0.00~100	1.00~36.0	1.00~570	0.00~146
N	27170	33620	32625	33363	34104	33847	32770	32770
	NO_X (ppb)	**CH_4** (ppm)	**NMHC** (ppm)	**THC** (ppm)	**O_3** (ppb)	**CO** (ppm)	**PM10** (μg m^{-3})	
Mean±SD	82.8±69.1	3.03±4.27	1.52±2.02	3.42±4.95	14.7±16.9	1.26±3.17	58.0±71.5	
Range	2.00~678	0.00~59.0	0.00~37.8	0.00~68.0	0.00~155	0.00~47.0	1.00~2946	
N	32770	30858	30848	30858	32690	32328	31301	

Table 1. A statistical summary of Hg and relevant environmental parameters determined concurrently during this study period

Most importantly, they found the moderately low concentration of 2.1 ng m^{-3} at the

Bridgeport site which was selected to represent the most industrialized area of all investigated sites. Similar to this observation, the presence of moderately low Hg concentration levels in urbanized regions has been found more commonly in many Western countries (e.g., Ames et al., 1998) or in rural areas affected by certain anthropogenic activities (Lee et al., 1998). It may be thus reasonable to infer that the Hg levels in many Western countries are controlled in a reasonably efficient manner than in many Eastern countries. In addition, our measurement data at Seoul can be further compared to those results made in a relatively clean area in Korea. In our recent study made in Kang Hwa Island, Korea for the two consecutive spring periods, we observed the mean concentrations of Hg to range from 2.57 (spring 2002) to 3.72 ng m^{-3} (spring 2001) (Kim et al., 2003).

REFERENCES

Ames, M., Gullu, G., Olmez, I., 1998, Atmospheric mercury in the vapor phase, and in fine and coarse particulate matter at Perch river, New York. Atmos. Environment 32, 865-872.

Artaxo, P., de Campos, R. C., Fernandes, E. T., Martins, J. V., Xiao, Z., Lindqvist, O., Fernandez-Jimenez, M. T., and Maenhaut, W., 2000, Large scale mercury and trace element measurements in the Amazon basin, Atmospheric Environment 34, 4,085-4,096.

Kim, K.-H. and Kim, M.-Y., 1999, The exchange of gaseous mercury across soil-air interface in a residential area of Seoul, Korea Atmospheric Environment 33, 3153-3165.

Kim, K.-H. and Kim, M.-Y., 2000, The effects of anthropogenic sources on temporal distribution characteristics of total gaseous mercury in Korea. Atmospheric Environment. 34, 3337-3347.

Kim, K.-H. and Kim, M.-Y., 2001. The temporal distribution characteristics of total gaseous mercury at an urban monitoring site in Seoul during 1999 to 2000. Atmospheric Environment. 35(25), 4253-4263.

Kim, K.-H. and Kim, M.-Y., 2002. A decadal shift in total gaseous mercury concentration levels in Seoul, Korea: changes between the late 1980s and the late 1990s. Atmospheric Environment. 36, 663-675.

Kim, K.-H., Kim, M. Y., Kim, J. and Lee, G., 2002. The concentrations and fluxes of total gaseous mercury in a western coastal area of Korea during the spring period, 2001. Atmospheric Environment. 36(21), 63-77.

Kim, K.-H., Kim, M. Y., Kim, J., Lee, G., 2003. Effects of changes in environmental conditions on atmospheric mercury exchange: Comparative analysis from a rice paddy field during the two spring periods of 2001 and 2002. J. Geophys. Res., 108(D19),

4607, doi: 10.1029/2003JD003375
Lee, D.S., Dollard, G.J., Pepler, S., 1998. Gas-phase mercury in the atmosphere of the United Kingdom. Atmospheric Environment. 32, 855-864.
Lindberg, S. E., Kim, K.-H., Meyers, T. P., Owens, J. G., 1995. Micrometeorological gradient approach for quantifying air/surface exchange of mercury vapor: Tests over contaminated soils. Environmental Science and Technology 29(1), 126-135.
Nadim, F., Perkins, C., Liu, S., Carley, R.J., Hoag, G.E.,2001. Long-term investigation of atmospheric mercury contamination in Connecticut. Chemosphere, 45, 1033-1043.
Pirrone, N., Allegrini, I., Keeler, G.J., Nriagu, J.O., Rossman, R., and Robbins, J.A., 1996. Historical atmospheric mercury emissions and depositions in North America compared to mercury accumulations in sedimentary records. Atmospheric Environment 32(5), 929-940.
Slemr, F., Scheel, H.E., 1998. Trends in atmospheric mercury concentrations at the summit of the Wank mountain, southern Germany. Atmospheric environment 32(5), 845-853.
Tan, H., He, J.L., Liang, L., Lazoff, S., Sommer, J., Xiao, Z.F., and Lindqvist, O., 2000. Atmospheric mercury deposition in Guizhou, China. Science of the Total Environment. 259, 223-230.