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A Review on Total Gaseous Mercury Concentration Levels in the East Asia

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Abstract: In this work, the present concentration levels of total gaseous mercury (TGM) are compared among three East Asian countries, Korea, China, and Japan. Comparison of Hg distribution patterns was made by selecting representative figures for each type of land use among those three countries. The results of the analysis indicate that Hg concentrations within a country can fall into a wide range due probably to the diversity of source processes. It is seen that the urban areas of China and Japan generally exhibit large spatial variability with notably high Hg levels (above 10 ng m^{-3}), compared to their Korean counterparts. Although the presence of high Hg levels in Chinese locations can be accounted for by the major man-made source processes (e.g., the use of coal), the causes of unexpectedly high Hg data in Japanese sites appear to be rather complicated. The Hg concentration levels in relatively remote locations however show much reduced values, above 3 ng m^{-3}, which is still higher than the typical background concentrations of 1 to 2 ng m^{-3} in Europe or America. Considering that the presence of unusually high Hg levels in urban areas of Asia is the consequence of man-made activities, the prevalence of excessively high Hg values in certain regions of the Asian continent needs further research to accurately assess the fundamental picture of Hg geochemistry in the East Asia.

Keywords : mercury, East Asia, Korea, China, Japan, source processes

Introduction

The atmospheric pollution of mercury (Hg) has existed for a long time, as the mercury amalgamation process (e.g., patio) has been practiced since ancient times (e.g., Blanchard, 1980). The consumption of Hg associated with gold and silver mining activities was known to comprise the major fraction of global Hg emissions in past centuries. Although this type of source process is still crucial in certain regions of the globe (e.g., Central and South America: Artaxo *et al.*, 2000; Pirrone *et al.*, 1998), diversification of source processes is apparent in many industrialized countries and regions (e.g., Kim and Kim, 2002). Investigation of Hg temporal trends indicates that the Hg levels are decreasing through time in certain regions where its pollution is by and large in the controllable stage (e.g., Lee *et al.*, 1998). However, the overall temporal trend of Hg is believed to increase due largely to the contribution of fast industrializing regions of the world including countries like China in the East Asia (Pirrone *et al.*, 1996).

Despite the expectation of a potent role for East Asia in the global Hg budget, there is yet a great hiatus on information concerning the distribution and mobilization characteristics of Hg in this region. The present status of Asia hence contrasts sharply with Europe and America, as the Hg database (DB) for those continents is well-documented and abundant. Although the DB deficiency in Asia was significant prior to the 90s, much progress made in recent years for the extension of Hg DB allows us to partially characterize Hg distribution patterns in Asia. It has in fact been demonstrated that Hg levels in this region have changed significantly over the past decades. Comparative analysis of Hg in Seoul, Korea indicated a three-fold reduction of Hg concentrations from the late 80s to the late 90s (Kim and Kim, 2002). According to this study, the causes of exceptionally high mean values of around 15 ng m^{-3} seen during the late 80s

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were mainly ascribable to the peak consumption rate of anthracite coal during that period.

In this work, I attempt to describe a representative picture of the present Hg distribution patterns in the East Asian countries through compilation of the most updated data sets reported from Korea, China, and Japan. As most atmospheric Hg research in the Asian continents has been conducted in these three countries, this review analysis can be used to evaluate the relative significance of Hg distribution characteristics in East Asia. The results of this comparative analysis can also provide a basis to understand the fundamental aspects of Hg geochemistry in the Asian continent.

Materials and Methods

In the present study, to make parallel comparisons of observed Hg levels between different countries, the concentration data on Hg were classified basically by land use type. However, because of large differences in experimental approaches between different studies, representative figures for a given site were derived in a complicated manner as described below. In the cases where the measurements were made intensively at a single spot for a given study, its mean Hg value was taken directly for that specific site. On the other hand if multiple sites of a similar nature were investigated for a similar study period, the average value for all study sites was used as the representative number. For instance, a single mean value was derived for mountainous area in Korea using the data sets reported by Kim and Kim (1996), who investigated 13 different sites during the similar period. By contrast, if many different types of site were investigated concurrently, the mean values for each site were used to represent each individual site. For instance, Liu *et al.* (2002) undertook the measurements from a number of Beijing sites with highly distinctive characteristics (such as industrial, residential, rural, and so on). Hence, the values they selected for each land use type should be considered as representative figures for diverse land use types in China.

Acknowledging differences in the potential impacts of different source processes in a given locale, mean concentration data for different land use types (e.g., industrial, commercial, residential, and grassland) were estimated by the above procedures. In addition to the compilation of the Hg levels in various urban areas, evaluation of the Hg data was further extended to derive representative figures for relatively clean, background-like environments in these Asian countries. For this purpose, the data from relatively remote areas including mountain and oceanic sites were compared.

Results and Discussion

Table 1 presents a summary of Hg measurement data for all different land use types among three different countries. It appears that the magnitude and frequency of Hg data obtained by different studies differ to a large extent. For instance while the mean value for a residential area in Seoul is derived from over 11,000 data points, that for oceanic areas of Japan was determined by only four data points. In addition, the mean values in Korean study sites were generally less variable, but those of China exhibited large spatial variabilities in measured concentrations. The Chinese results, derived mainly from the study of Liu *et al.* (2002), do not provide accurate information on the magnitude of data points, but their measurement frequency appears to fall in between the Korean and Japanese counterparts.

The results of this comparative analysis indicate that the Hg distribution patterns among three countries are compatible in many respects, while large differences also exist. In the case of industrial areas, the results of Japan are larger than those of China by 4 to 5 times, while no data are available for Korea. Because of many inherent limitations however, it is yet difficult to assign any signifi-

Table 1a. Comparison of atmospheric Hg concentrations determined from East Asian countries.

	Data Group	Industrial	Residential	Commercial	Rural	Remote
	1		5.25[1]*	5.34[2]		4.47[3]
Korea	2		5.26[4]	6.54[5]		7.03[6]
	3					3.15[7]
Japan	1	31.6[8]	10.3[9]		5.73[10]	3.4[11]
	2		16.5[12]		42.4[13]	
China	1	6.75[14]	16.7[15]	10.5[16]	3.75[17]	3.35[18]
	2		8.47[19]			

*For detailed information of superscripts, refer to reference number provided in Table 2.

Table 1b. Source information for the Hg data provided in Table 1a. All the reference nos. are identical to those given in Table 1a.

Ref. No.	Site	City/Province	Study period	Number of data*	Author
A. Korea					
1		Kwa Chun	99~00	1992	Kim and Kim, 2001b
2	Han Nam	Seoul City	99~00	2576	Kim and Kim, 2001b
3	13 Mountains	Nationwide	87~93	32	Kim and Kim, 1996
4	Yang Jae	Seoul City	99~00	11572	Kim and Kim, 2001a
5	3 Terminals	Seoul City	Mar. 98	349	Kim and Kim, 2001c
6	2 Mountains		97/98	358	Kim and Kim, 2001c
7	Hari	Kang Hwa Island	01/02	323	Kim *et al.*, in prep.
B. Japan					
8		Chiba and two others	91~96/94	40	Nakagawa and Hiromoto, 1997
9	urban areas	Chiba and three others	91~96/95	216	Nakagawa and Hiromoto, 1997
10	suburban	Kushiro and two others	91, 94, 95	31	Nakagawa and Hiromoto, 1997
11	Oceans	Japan sea/pacific	91	4	Nakagawa and Hiromoto, 1997
12	rural city	Hayama and two others	91~96, 95, 96	64	Nakagawa and Hiromoto, 1997
13	Farmland	Tukui and two others	95/93	15	Nakagawa and Hiromoto, 1997
C. China					
14	Shijingshan	Beijing	Feb. & Sept. 98	12 days	Liu *et al.*, 2002
15	Xuanwu	Beijing	Jan. & Sept. 98	9 days	Liu *et al.*, 2002
16	Tiananmen Sq.	Beijing	Feb. & Sept. 98	8 days	Liu *et al.*, 2002
17	two rural sites	Beijing	Feb. & Sept. 98	9 days	Liu *et al.*, 2002
18	Mountain sites	Guizhou	Unreported	122	Tan *et al.*, 2000
19	residential	Beijing	Jan. & Feb. 98	15 days	Liu *et al.*, 2002

*For data provided by Liu *et al.*, all information is given as number of days.

cance to the industrial Hg levels from this analysis. On the other hand, the Hg DB for residential areas is abundant enough to allow examination of various aspects of major man-made source processes (e.g., Kim and Kim, 2001). The mean Hg levels for the two different Korean residential sites, while derived from reasonably large data points, are highly coincident with the similar mean values of 5.25 and 5.26 ng m^{-3}. The situation is however largely different in Japan and China, as the site characteristics for urban stations are not clearly defined in many occasions. In handling the datasets of Japan, those obtained at urban sites in Chiba, Tokyo, and others (10.3 ng m^{-3}) and rural cities in Hayama and others (16.5 ng m^{-3}), as they were not descriptively designated, were taken as residential sites. The situation is slightly different in China, as the authors investigated various study sites within the city of Beijing. Although Xuanwu site was specifically allocated as a residential site with a mean concentration of 16.7 ng m^{-3}, the data from Research Center sites with a mean value of 8.47 ng m^{-3} were classified as suburban sites. However because the latter sites are also in the vicinity of urban areas in Beijing, they were arbitrarily grouped as residential areas. The prevalence of notably high Hg concentration levels in those residential areas of Japan and China relative to Korea appears to be highly meaningful. The magnitude of Hg concentrations in the residential areas of the two countries is in fact remarkably compatible with what was found in the late 80s in Seoul, Korea (Kim and Kim, 2002). Explanations for such occurrences between the two countries may, however, be sought from different aspects. As the consumption of coal increased rapidly in China, the observed Hg values in Chinese residential areas may be accounted for by such source processes as household heating. However, because no prominent source processes can be assigned to the observed Hg levels in Japan, the concentrations above 10 ng m^{-3} in Japanese residential areas need to be studied further for possible explanations. It is however interesting to note that urban areas on the leeward side of the volcanic activity exhibit a mean concentration for four seasons at 10.3 ng m^{-3} (Tomiyasu *et al.*, 2000). On the other hand, the results for commercial areas in the Asian countries exhibit a large similarity to the patterns seen from residential ones. While data for Japan are not available, the results from Korea and China cannot clearly be distinguished from what were seen at their residential counterparts. The generally enhanced Hg levels in Chinese commercial areas may still be explained by the broad effects of coal use in modern China.

The Hg concentration levels in rural areas are notably different from the results seen in urbanized areas. Although data for this category are not available in Korea, the results from Japan and China are found at the notably reduced values of 3 to 5 ng m^{-3}. However, the existence of exceptionally high values (42.4 ng m^{-3}) in cultivated regions of Japan draws special attention. According to Nakagawa and Hiromoto (1997), these exceptionally high Hg levels may reflect the widespread application of agricultural fungicides in the past. As these values represent the atmospheric concentrations of a few farmland areas including Tukui, Sagami, and Niigata (1993~1995), future studies may be needed to examine how widely those phenomena are present and how variable their temporal patterns are through time. This level of Hg concentration in fact appears to be one of the highest values measured previously under strong man-made activities. For instance, the mean values for highly polluted urban air did not exceed 20 ng m^{-3} (Kim and Kim, 2000). In addition, the Hg concentrations above Hg-contaminated floodplains were still on the order of a few ng m^{-3} (Lindberg *et al.*, 1995). However, there are also records for areas exposed by pronouncedly strong source processes (e.g., factory areas of Hg mines in China) wherein the Hg concentrations were above a few hundred ng m^{-3} (Xiao *et al.*, 1998).

At present, a very limited number of studies have been directed to the measurements of the background concentration levels of Hg in the Asian continents. As a simple means to assess the background Hg levels in Asia, the Hg concentration data determined from relatively remote areas were compared. The lowest values for this category were found from Kang Hwa Island in Korea during measurements made in March 2001 (Kim *et al.*, 2002) and in April 2002 (Kim *et al.*, in prep.) The results obtained from oceanic regions of Japan (3.4 ng m^{-3}) are highly comparable to those seen from high mountainous sites in China (3.35 ng m^{-3}), while relatively high Hg concentrations seen at Korean mountainous sites (4~7 ng m^{-3}) suggest that the effects of man-made activities can still be effective in relatively clean environments of a country with high population density.

Because of large gaps in control strategies and techniques between different countries, comparison of background (or background-like) concentration levels of Hg can be very meaningful. If one assumes that there are large differences in the basic components of the present time major anthropogenic source processes of Hg between different continents, such attempts can help distinguish the potent role of anthropogenic source processes in a given environment. The presence of abnormally high concentrations in concert with wide concentration variabilities in the East Asian countries suggests that the distribution of Hg in this region is compatible with those typically found at rapidly developing, rather than developed, regions on the globe (e.g., Hladikova *et al.*, 2001).

Conclusion

In the present study, the distribution characteristics of Hg in East Asia were assessed by comparing the Hg measurement data from three countries, Korea, Japan, and China. The results of this analysis indicate that the Hg DB is large enough for certain locations, while most of investigated sites suffer from deficiency of DB. It is still difficult to derive the precise picture of Hg distributions in this region. However, results from different regions still exhibit similar signatures in Hg source processes that are tightly bound with man-made activities including the use of fossil fuels. The data from different countries show certain trends of their own. In Korea, spatial variabilities in Hg distributions appear to be in most cases of minor significance, as the values tend to exhibit large similarities. By contrast, the patterns for China are quite contrary to those of Korea; large spatial variabilities exist in observed Hg levels within the same district boundary (e.g., Beijing, China). Moreover if one considers the peculiar patterns found from certain sites in Japan (e.g., abnormal values from farmland areas), further studies are necessary to explain more accurately the temporal and spatial distribution patterns of Hg under various environmental settings. The observed distribution patterns of Hg in the three countries appear to be complicated enough to a large extent because of different situations to which different countries are subject. As such, it is reasonable to expect that there may be large differences in the source strengths of different processes that can exert certain controls on Hg behavior in the atmospheres of East Asia.

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