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Three years of atmospheric total gaseous and particulate mercury measurement in Taiwan

Chi-Fu Yeh[1*], Peter Brimblecombe[2] , Chin-Hsing Lai[3]

[1*] *Hwa-Ying Environment Technical Consultants Co. Ltd., No. 29-81, Feng-Ren District, Kaohsiung 81463, Taiwan*

[2]*School of Energy and Environment, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong SAR3*

[3]*Department of Environmental Engineering and Science, Fooyin University, No. 151 Chin-Hsueh Rd., Ta-Liao District, Kaohsiung 83102, Taiwan*

**Corresponding author: wastonyeh@gmail.com; Tel: +886-7-374-5812*

1. INTRODUCTION

Mercury is a toxic pollutant across USEPA programs, including air, water, and hazardous waste. Mercury exists in three different chemical forms (gaseous elemental mercury (GEM), gaseous oxidized mercury (GOM), and particulate-bound mercury (Hg_p)).The atmospheric residence time of gaseous element mercury (GEM) is 0.5-2 years and can transport over long distance (Duan et al., 2017). In contrast, Gaseous oxidized mercury (GOM) and particulate mercury (Hg_p) have a lifetimes of hours to weeks (Mao et al., 2017). In this study, three years of atmospheric mercury investigation were conducted to understand the effect of seasonal variation of early southwestern monsoon (May/Spring) and early northeastern monsoon (October/Fall). In addition, different land use on the effect of atmospheric mercury concentration was also investigated.

2. MONITORING METHODS AND ANALYSIS

Total gaseous mercury (TGM) and particulate mercury (Hg_p) were determined in twenty-one sampling sites in Taiwan. Twelve sites belong to urban spots and the rest of nine sites belong to source sites. NIEA Method A 304.10C (Taiwan EPA) was chosen collect TGM (GEM+GOM) and Hg_p in a metal free sampling box 3 m above the ground. TGM was collected by gold-trap sands (Brooksrand, USA), while Hg_p was collected on the glass-fiber filters (Whatman 934-AH, USA). TGM and Hg_p were continuously collected for 24 hrs at each sampling site. The sampling campaign was focused on early southwestern monsoon (May) and early northeastern monsoon season (October) from 2013 to 2015. TGM and Hg_p samples were processed in a class 1,000 clean room with class 100 clean bench. TGM and Hg_p were determined by cold vapor atomic fluorescence spectrometry (Broosrand Model III, USA and NIC model WA-5F, Japan).

3. RESULTS AND DISCUSSION

3.1 Concentrations of mercury measurement from 2013 to 2015

Table 1 summaries the concentrations of PM_{10}, TGM, and Hg_p in western Taiwan during the three years monitoring campaign. Source sites demonstrated higher TGM and Hg_p concentrations than those of the urban monitoring sites. The low RSDs of TGM in urban and source sites indicated that TGM were relatively consistent than great variability of Hg_p. Over the entire sampling campaign (2013-2015),

Table 1. A statistical summary of PM_{10} (μg/m³), TGM (ng/m³), and Hg_p (pg/m³) concentrations in this study.

		Urban				Source			
		Mean	RSD (%)	Min	Max	Mean	RSD (%)	Min	Max
2013	PM_{10}	46.1	62.6	16.2	110	54.3	43.1	22.9	93.0
	TGM	3.08	32.8	1.11	7.44	5.70	106	1.45	25.5
	Hg_p	46.7	59.7	10.6	152	127	199	9.24	938
2014	PM_{10}	43.5	56.7	17.5	92.3	49.8	62.7	11.7	99.8
	TGM	2.81	26.5	1.38	4.25	3.75	68.6	1.58	11.0
	Hg_p	50.9	67.6	9.95	127	149	172	5.92	913
2015	PM_{10}	50.7	63.1	17.0	154	55.1	63.3	14.2	139
	TGM	3.02	42.7	0.94	6.69	3.17	34.6	1.43	6.37
	Hg_p	37.9	68.6	5.54	114	79.8	92.6	10.9	268
2013-2015	PM_{10}	46.8	60.8	16.2	154	53.1	56.0	11.7	139
	TGM	2.97	34.7	0.94	7.44	4.21	93.0	1.43	25.5
	Hg_p	45.1	65.9	5.54	152	119	160	5.92	938

3.2 Seasonal variation of mercury in urban and source sites

The seasonal mean concentrations of TGM and Hg_p over the three years sampling campaign in urban and source sites are shown in Figure 1.

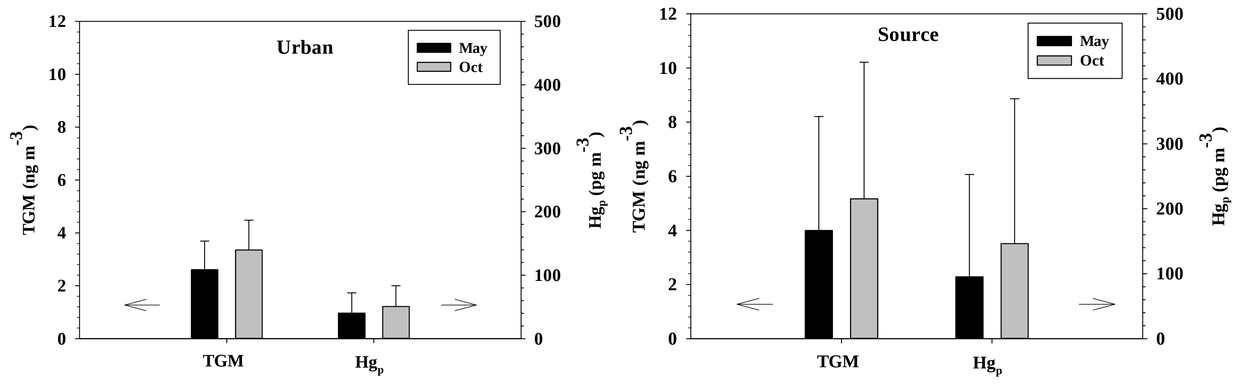

Figure 1. Seasonal mean concentrations of TGM and Hg_p over the three years sampling campaign in urban and source sites.

Table 2 presents the results of the analysis of variance by using Rstudio with month (May and October) and land use. The month factor had significant effect ($p < 0.05$) on PM_{10}, TGM, and Hg_p. while, the land use factor had significant effect ($p < 0.05$) on TGM and Hg_p.

Table 2. Results of the analysis of variance on the PM_{10}, TGM, and Hg_p concentrations by using Rstudio with month and land use.

Source	DF[a]	SS[a]	MS[a]	F value	P-value
PM_{10}					
Month	1	37161	37161	69.9	1.48e-13
Land use	1	1353	1353	2.545	0.113
Residuals	117	62180	531		
TGM					
Month	1	38.6	38.65	5.359	0.0224
Land use	1	43.1	43.14	5.982	0.0159
Residuals	117	843.8	7.21		
Hg_p					
Month	1	13926	13926	0.831	0.3640
Land use	1	159948	159948	9.539	0.0025
Residuals	117	1961797	16767		

DF[a] = Degree of freedom, SS[a] = sums of squares, MS[a] = mean squares

3.3 Distribution of Hg concentrations in sampling campaigns from 2013 to 2015

To understand the distribution of TGM and Hg_p concentrations in urban and source sites, the frequency distributions are analysed and shown in Figure 2.

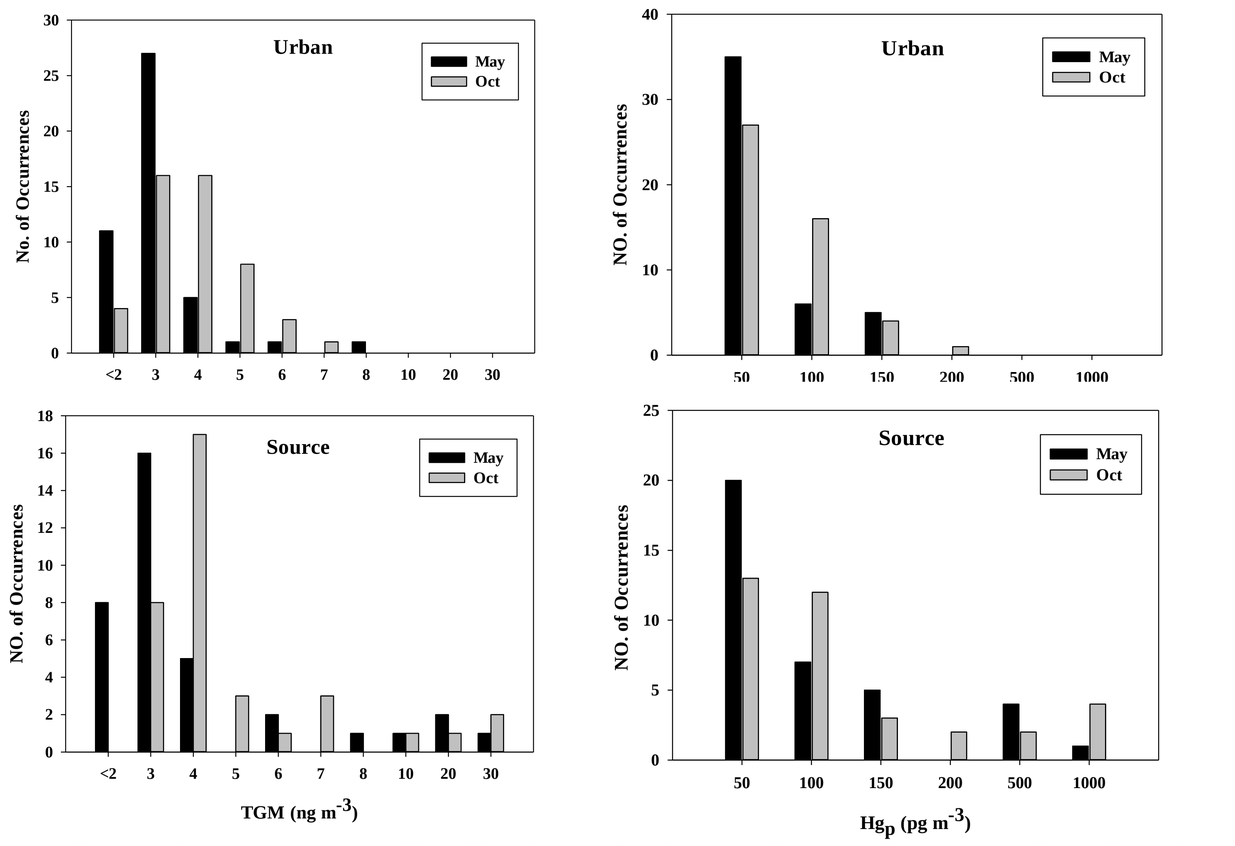

Figure 2. Frequency distribution of TGM and Hg_p concentration data in sampling campaigns from 2013 to 2015.

3.4 TGM to Hg_p ratio distribution

Figure 3 shows the TGM to Hg_p ratios of the 96 points in urban sites and 72 points in source sites. High Hg_p/GEM ratio (average 40%) was also observed at iron-steel industrial area in China (Han et al., 2019).

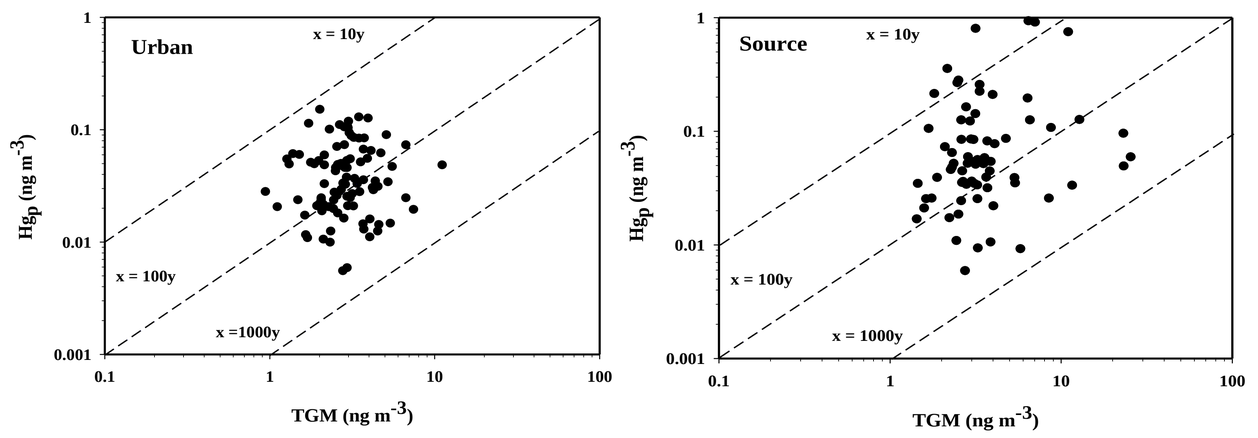

Figure 3. TGM and Hg_p concentration ratios in urban and source sites in western Taiwan from 2013 to 2015.

4. CONCLUSIONS

Seasonal variation showed the higher concentrations of TGM and Hg_p were observed in Fall (October) than those of in Spring (May). Source sites demonstrated the higher TGM and Hg_p concentrations than those of in urban monitoring sites. In source sites, high concentrations of TGM and Hg_p was measured at cement and stainless steel plant monitoring sites. The major chemical form of ambient mercury was TGM, more than 95% in most urban and source monitoring sites.

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