Monitoring of ambient Hg in urban and other locations of Korea and its emissions from various man-made sources

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Section 1.

AQM for Hg in urban, regional background, and industrial area

A. Hg level changes in the capital city, Seoul: late 80s to the present

Kim K.-H. and Kim M. Y. (2002)
A decadal shift in total gaseous mercury concentration levels in Seoul, Korea: Changes between the late 80s and the late 90s.
Atmospheric Environment 36(4), 663-675.

Kim K.-H., Shon Z.-H., Nguyen H. T., Jung K., Bae G.-N. (2011)
The effect of man-made source processes on the behavior of total gaseous mercury in air: a comparison between four urban monitoring sites in Seoul, Korea.
Science of Total Environment. 409, 3801-3811. HS09

B. Regional background area in Korea: Jeju Island

Nguyen H.T., Kim K.-H.*, Kim M.-Y. (2010)
The influence of long range transport on atmospheric mercury on Jeju Island, Korea.
Sci. Total Environment 408, 1295-1307.

C. Urban industrial area in Korea: Ban Wall Industrial area

Nguyen H.T., Kim K.-H.*, Kim M.-Y., Kang C.-H., Shim S.-G. (2008)
Mercury in air in an area impacted by strong industrial activities.
Chemosphere 71(11), 2017-2029.

Section 1.

AQM for Hg in urban, regional background, and industrial area

A. Hg level changes in the capital city, Seoul: late 80s to the present

Fig. 1-1. Locations of the four urban AQM stations in Seoul, Korea

G (GuRo Gu); N (NoWon Gu); S (SongPa Gu); and Y (YongSan Gu).

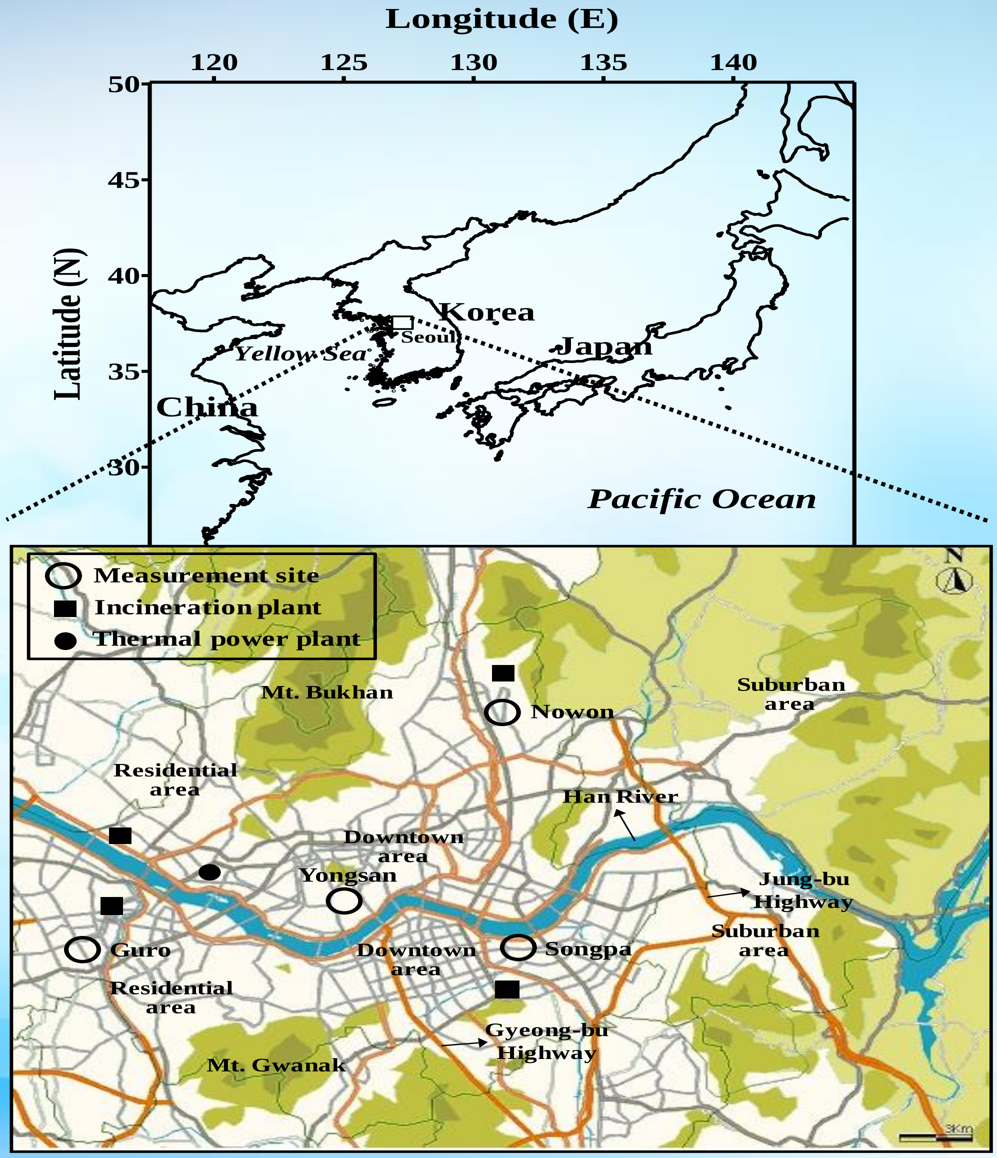


Table 1-1. Urban air quality in late 80s to early 00s (Site Y (Hannam dong, Yong San district), Seoul, Korea) – Kim and Kim (2002)

	I. Sept. '87~ Oct. '88			II. Sept. '99~ July '00		
	All data	Annual		All data	Annual	
		1987	1988		1999	2000
Hg (ng m^{-3})	14.4±9.56 (N=2714) R=4.73~113	15.3±10.2 (N=810) R=4.73~113	14.0±9.23 (N=1904) R=5.09~109	5.34±3.92 (N=2576) R=0.56~80.1	5.23±3.12 (N=850) R=0.56~18.3	5.39±4.26 (N=1726) R=1.04~80.1
SO_2 (ppb)	6.57±5.12 (N=5721)	7.20±5.27 (N=2367)	6.12±4.96 (N=3354)	6.28±2.90 (N=6762)	5.37±2.48 (N=2483)	6.81±2.99 (N=4279)
NO (ppb)	61.8±53.4 (N=8559)	84.4±59.8 (N=2512)	52.4±47.5 (N=6047)	43.3±48.4 (N=6734)	64.4±60.4 (N=2436)	31.3±34.7 (N=4298)
NO_2 (ppb)	21.9±15.1 (N=8559)	15.1±10.4 (N=2511)	24.7±15.8 (N=6048)	41.3±21.2 (N=6734)	42.2±17.2 (N=2436)	40.7±23.1 (N=4298)
NOX (ppb)	83.7±57.5 (N=8558)	99.5±62.9 (N=2511)	77.1±53.7 (N=6047)	84.5±62.1 (N=6734)	107±73.2 (N=2436)	72.0±50.8 (N=4298)
CH_4 (ppm)	1.96±0.58 (N=5236)	1.84±0.51 (N=2364)	2.06±0.62 (N=2872)	2.31±0.39 (N=6077)	2.37±0.33 (N=2379)	2.27±0.42 (N=3698)
NMHC (ppm)	0.64±0.64 (N=5237)	0.79±0.75 (N=2364)	0.51±0.50 (N=2873)	0.61±0.48 (N=6077)	0.84±0.55 (N=2379)	0.47±0.35 (N=3698)
THC (ppm)	2.60±0.93 (N=5236)	2.64±1.00 (N=2364)	2.57±0.86 (N=2872)	2.92±0.73 (N=6077)	3.21±0.78 (N=2379)	2.74±0.63 (N=3698)
O_3 (ppb)	10.2±15.8 (N=8218)	6.81±14.0 (N=2357)	11.6±16.3 (N=5861)	15.8±14.8 (N=6801)	8.90±9.21 (N=2503)	19.8±16.0 (N=4298)
CO (ppm)	2.54±2.60 (N=8070)	3.32±3.26 (N=1925)	2.29±2.31 (N=6145)	1.15±0.67 (N=6589)	1.29±0.84 (N=2291)	1.07±0.54 (N=4298)
PM10 ($\mu g\ m^{-3}$)	143±96.6 (N=8022)	142±93.5 (N=2437)	143±98.0 (N=5585)	65.6±47.9 (N=2492)	-	65.6±47.9 (N=2492)

Table 1-2. A statistical summary of Hg and relevant environmental parameters at site Y between late 80s and late 90s.

	Seasonal				Seasonal			
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
	Hannam 87-88				Hannam 99-00			
Hg (ng m^{-3})	11.6±4.36 (N=528) R=5.82~42.2	12.4±6.22 (N=662) R=5.09~50.9	14.5±8.59 (N=962) R=4.73~113	19.2±14.7 (N=562) R=5.82~109	5.07±2.67 (N=239) R=1.04~13.2	5.37±2.36 (N=734) R=2.14~25.7	5.23±3.12 (N=850) R=0.56~18.3	5.51±5.82 (N=753) R=1.65~80.1
SO_2 (ppb)	8.77±3.99 (N=1598)	1.47±0.46 (N=1101)	5.77±4.96 (N=1956)	9.97±4.97 (N=1066)	7.13±2.95 (N=2194)	5.04±3.01 (N=719)	4.83±2.27 (N=1765)	7.05±2.62 (N=2084)
NO (ppb)	54.4±45.6 (N=1944)	36.3±36.9 (N=1583)	66.1±54.5 (N=3263)	84.8±60.1 (N=1769)	30.9±34.0 (N=2195)	25.1±33.6 (N=742)	59.8±55.8 (N=1696)	49.2±53.3 (N=2101)
NO_2 (ppb)	31.0±18.2 (N=1944)	27.3±15.7 (N=1583)	17.4±11.6 (N=3262)	15.3±8.27 (N=1770)	43.0±17.3 (N=2195)	52.4±38.9 (N=742)	41.8±17.4 (N=1696)	35.2±16.2 (N=2101)
NOX (ppb)	85.4±54.4 (N=1944)	63.6±45.5 (N=1583)	83.5±58.6 (N=3262)	100±62.7 (N=1769)	73.9±47.0 (N=2195)	77.4±65.0 (N=742)	102±67.9 (N=1696)	84.4±67.0 (N=2101)
CH_4 (ppm)	2.02±0.60 (N=1261)	2.34±0.93 (N=299)	1.92±0.54 (N=2598)	1.88±0.49 (N=1078)	2.28±0.47 (N=1828)	2.20±0.51 (N=550)	2.37±0.34 (N=1737)	2.30±0.29 (N=1962)
NMHC (ppm)	0.46±0.47 (N=1261)	0.40±0.25 (N=300)	0.54±0.58 (N=2598)	1.15±0.73 (N=1078)	0.36±0.21 (N=1828)	0.37±0.21 (N=550)	0.82±0.53 (N=1737)	0.73±0.52 (N=1962)
THC (ppm)	2.49±0.91 (N=1261)	2.75±1.03 (N=299)	2.46±0.87 (N=2598)	3.03±0.91 (N=1078)	2.65±0.62 (N=1828)	2.57±0.61 (N=550)	3.19±0.79 (N=1737)	3.03±0.67 (N=1962)
O_3 (ppb)	17.0±19.8 (N=2039)	10.7±14.9 (N=1589)	8.37±14.2 (N=2821)	4.77±10.3 (N=1769)	22.9±15.2 (N=2195)	25.6±22.0 (N=742)	9.11±9.94 (N=1763)	10.5±8.17 (N=2101)
CO (ppm)	2.38±2.01 (N=2046)	0.98±0.52 (N=1581)	2.39±2.24 (N=2676)	4.34±3.59 (N=1767)	0.99±0.45 (N=2192)	0.94±0.44 (N=742)	1.27±0.87 (N=1552)	1.29±0.69 (N=2103)
PM10 (μg m^{-3})	142±85.9 (N=2016)	133±97.0 (N=1186)	161±105 (N=3191)	113±82.1 (N=1629)	59.9±38.5 (N=2007)	89.1±70.6 (N=485)	-	-

Table 1-3. A statistic summary of Hg concentration measured at four urban sites (Y (Yongsan), N (Nowon), G (Guro), and S (Songpa)) between '04-'09 Kim et al. (2011)

Parameter (unit)		Y		N		G		S	
		Mean ± SD (Median)	Range (N)	Mean ± SD (Median)	Range (N)	Mean ± SD (Median)	Range (N)	Mean ± SD (Median)	Range (N)
A. Pollutant species									
Hg	(ng m^{-3})	3.36 ± 1.55 (3.26)	0.01 - 13.3 (1925)	3.98 ± 1.68 (3.83)	0.09 - 19.8 (1945)	3.80 ± 1.60 (3.53)	0.06 - 14.4 (1892)	3.87 ± 1.56 (3.80)	0.05 - 16.8 (1880)
$PM_{2.5}$	(mg m^{-3})	28.0 ± 17.6 (24.0)	2.00 - 237 (2075)	29.3 ± 16.4 (26.0)	3.00 - 114 (1734)	29.3 ± 17.7 (16.0)	4.00 - 112 (1006)	27.8 ± 16.5 (24.0)	3.00 - 112 (2121)
PM_{10}	(mg m^{-3})	58.9 ± 44.6 (50.0)	6.00 - 1157 (2080)	56.1 ± 36.8 (49.0)	6.00 - 779 (2118)	57.4 ± 39.5 (50.0)	4.00 - 848 (2132)	57.6 ± 43.0 (50.0)	6.00 - 1075 (2130)
TSP	(mg m^{-3})	79.6 ± 55.8 (69.0)	3.00 - 1301 (2078)	87.0 ± 56.2 (76.0)	12.0 - 1133 (2115)	80.8 ± 49.9 (70.0)	10.0 - 967 (2131)	84.4 ± 60.7 (73.0)	8.00 - 1427 (2126)
CH_4	ppm	2.06 ± 0.21 (2.05)	1.53 - 3.11 (1300)	2.01 ± 0.16 (2.00)	1.52 - 3.14 (2066)	2.02 ± 0.16 (2.00)	1.57 - 2.80 (2126)	1.94 ± 0.15 (1.92)	1.55 - 2.81 (1348)
CO	ppm	0.50 ± 0.27 (0.40)	0.10 - 2.20 (2066)	0.59 ± 0.30 (0.50)	0.10 - 2.00 (2106)	0.63 ± 0.29 (0.60)	0.10 - 2.10 (2130)	0.56 ± 0.29 (0.50)	0.10 - 2.00 (2120)
NO	ppm	0.03 ± 0.03 (0.02)	0.001 - 0.24 (1708)	0.02 ± 0.03 (0.01)	0.001 - 0.21 (1775)	0.03 ± 0.03 (0.02)	0.001 - 0.28 (1781)	0.03 ± 0.03 (0.02)	0.001 - 0.23 (1776)
NO_2	ppm	0.04 ± 0.02 (0.04)	0.001 - 0.10 (2042)	0.03 ± 0.01 (0.03)	0.001 - 0.10 (2109)	0.04 ± 0.02 (0.04)	0.01 - 0.11 (2115)	0.03 ± 0.01 (0.03)	0.01 - 0.10 (2110)
NO_x	ppm	0.07 ± 0.04 (0.06)	0.01 - 0.34 (1708)	0.05 ± 0.04 (0.04)	0.01 - 0.25 (1775)	0.07 ± 0.05 (0.05)	0.01 - 0.38 (1781)	0.07 ± 0.04 (0.05)	0.01 - 0.32 (1776)
SO_2	ppm	0.01 ± 0.003 (0.004)	0.001 - 0.02 (2078)	0.01 ± 0.005 (0.005)	0.001 - 0.02 (2106)	0.01 ± 0.003 (0.004)	0.001 - 0.02 (2138)	0.005 ± 0.003 (0.004)	0.0.0 - 0.02 (2118)
O_3	ppm	0.02 ± 0.01 (0.02)	0.001 - 0.06 (2058)	0.02 ± 0.01 (0.02)	0.001 - 0.07 (2116)	0.02 ± 0.01 (0.02)	0.001 - 0.07 (2129)	0.02 ± 0.01 (0.02)	0.001 - 0.08 (2119)
THC	ppm	2.45 ± 0.30 (2.42)	1.81 - 3.65 (1300)	2.37 ± 0.25 (2.36)	1.62 - 3.56 (2066)	2.37 ± 0.29 (2.31)	1.78 - 4.23 (2126)	2.20 ± 0.26 (2.15)	1.62 - 3.32 (1348)
NMHC	ppm	0.39 ± 0.21 (0.35)	0.02 - 1.52 (1300)	0.37 ± 0.16 (0.35)	0.07 - 1.24 (2064)	0.35 ± 0.19 (0.32)	0.02 - 1.68 (2126)	0.26 ± 0.15 (0.22)	0.01 - 1.28 (1348)
B. Meteorological parameters*									
TEMP	(°C)	13.2 ± 10.0 (15.0)	-13.8 - 30.5 (2074)	13.5 ± 9.92 (15.1)	-13.7 - 30.7 (2110)	14.3 ± 9.45 (15.9)	-11.1 - 31.3 (2071)	13.2 ± 9.93 (14.7)	-11.3 - 30.2 (2111)
RH	(%)	62.0 ± 16.0 (63.0)	19.0 - 96 (2085)	59.7 ± 15.7 (60.0)	21.0 - 98 (2120)	57.7 ± 14.5 (58.0)	18.0 - 98 (2076)	64.0 ± 14.9 (65.0)	24.0 - 98 (1959)
UV	(mW cm^{-2})	0.22 ± 0.21 (0.15)	0.01 - 0.99 (1938)	0.42 ± 0.28 (0.33)	0.01 - 1.55 (2120)	0.30 ± 0.19 (0.25)	0.01 - 0.93 (2091)	0.30 ± 0.22 (0.23)	0.01 - 1.07 (2093)
WS	(m s^{-1})	1.41 ± 0.79 (1.20)	0.20 - 4.50 (2085)	1.53 v 0.49 (1.40)	0.40 - 4.30 (2120)	1.68 ± 0.66 (1.60)	1.20 - 5.40 (2133)	0.92 ± 0.51 (0.80)	0.10 - 3.20 (2134)

* Acronyms used for meteorological parameters denote: TEMP = temperature, relative humidity = RH, Ultraviolet = UV, WS = wind speed,

Table 1-4. Comparison of the annual mean concentrations of Hg at the four urban locations: Yongsan (Y), Nowon (N), Guro (G), and Songpa (S).

Year	Y	Trend (%)	N	Trend (%)	G	Trend (%)	S	Trend (%)
All data	3.36 ± 1.55 (3.26)	0.1%	3.98 ± 1.68 (3.83)	0.1%	3.80 ± 1.60 (3.53)	0.05%	3.87 ± 1.56 (3.80)	0.05%
	0.01 - 13.3 (1925)		0.09 - 19.8 (1945)		0.06 - 14.4 (1892)		0.05 - 16.8 (1880)	
2004	2.89 ± 1.87 (2.80)		3.72 ± 1.49 (3.88)		3.41 ± 1.21 (3.33)		4.49 ± 1.37 (4.37)	
	0.03 - 7.89 (275)		0.09 - 7.57 (274)		0.06 - 8.19 (287)		0.05 - 9.66 (285)	
2005	3.23 ± 2.07 (3.47)	-12%	4.51 ± 2.02 (4.37)	-21%	3.30 ± 0.97 (3.37)	3%	3.11 ± 1.33 (3.23)	31%
	0.01 - 8.10 (324)		0.40 - 12.9 (301)		1.28 - 7.14 (287)		0.20 - 7.13 (274)	
2006	3.20 ± 1.24 (3.11)	1%	2.87 ± 1.25 (2.82)	37%	3.46 ± 1.27 (3.39)	-5%	2.72 ± 1.3 (2.59)	12%
	0.54 - 10.2 (300)		0.65 - 8.56 (335)		0.55 - 9.11 (351)		0.59 - 7.9 (291)	
2007	3.36 ± 1.37 (3.13)	-5%	4.34 ± 1.46 (4.29)	-51%	4.86 ± 1.86 (4.45)	-40%	4.16 ± 1.7 (3.94)	-53%
	1.07 - 9.46 (340)		0.68 - 16.01 (339)		1.59 - 14.41 (327)		1.36 - 16.83 (333)	
2008	3.45 ± 1.12 (3.29)	-3%	4.25 ± 1.63 (3.85)	2%	4.55 ± 1.95 (4.30)	6%	4.52 ± 1.34 (4.31)	-9%
	1.47 - 8.28 (352)		1.75 - 10.53 (363)		1.30 - 13.44 (312)		1.84 - 9.73 (363)	
2009	3.89 ± 1.31 (3.77)	-13%	4.16 ± 1.59 (3.94)	2%	3.19 ± 1.18 (3.04)	30%	3.96 ± 1.32 (3.87)	12%
	1.43 - 13.29 (334)		1.90 - 19.81 (333)		1.10 - 11.5 (328)		1.62 - 12.7 (334)	

Section 1.

AQM for Hg in urban, regional background, and industrial area

B. Regional background area in Korea: Jeju Island

Fig. 1-2. The geographical location of the study site (Gosan, Jeju island in Korea).

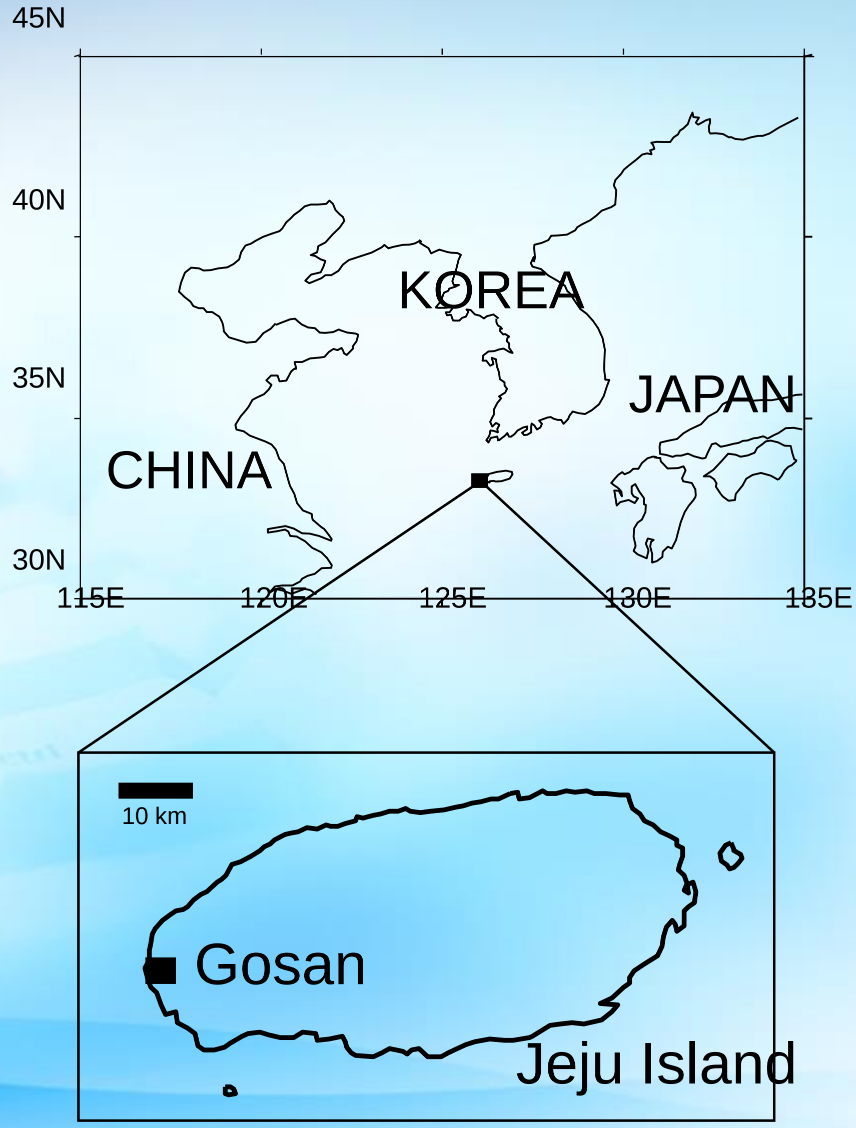


Table 1-5. A statistical summary of Hg concentration measured from May 2006 to May 2007 at Gosan, Jeju island

Parameter (unit)	All data	spring	summer	fall	winter
A. Hg pollution					
Hg (ng m^{-3})	3.85 ± 1.68 (3.58)	4.19 ± 2.04 (3.93)	3.98 ± 1.37 (3.68)	4.37 ± 1.31 (4.18)	2.59 ± 1.03 (2.46)
	0.10 - 17.9 (7450)	0.45 - 17.9 (2435)	1.86 - 9.30 (2077)	1.54 - 10.4 (1472)	0.10 - 9.09 (1466)
$Hg^{I]}$ (ng m^{-3})[a]	3.78 ± 1.50 (3.58)	3.98 ± 1.59 (3.86)	3.98 ± 1.37 (3.68)	4.37 ± 1.30 (4.18)	2.59 ± 1.03 (2.46)
	0.10 - 9.90 (7389)	0.45 - 9.9 (2375)	1.86 - 9.30 (2077)	1.54 - 9.40 (1471)	0.10 - 9.09 (1466)
$Hg^{II]}$ (ng m^{-3})[b]	12.1 ± 2.00 (11.7)	12.2 ± 2.00 (11.7)		10.4	
	10.0 - 17.9 (61)	10.0 - 17.9 (60)		(1)	
$Hg^{III]}$ (ng m^{-3})[c]	4.79 ± 3.82 (2.58)	4.82 ± 3.90 (2.56)		4.39	4.20 ± 2.61 (4.20)
	1.54 - 17.2 (62)	1.54 - 17.2 (59)		(1)	2.35 - 6.04 (2)
B. Other pollutants					
CO (ppm)	0.52 ± 0.22 (0.50)	0.48 ± 0.16 (0.50)	0.56 ± 0.21 (0.60)	0.55 ± 0.26 (0.50)	0.50 ± 0.23 (0.50)
	0.10 - 1.70 (8567)	0.10 - 1.50 (2477)	0.10 - 1.50 (1885)	0.10 - 1.30 (2058)	0.10 - 1.70 (2147)
NO_2 (ppb)	4.35 ± 2.85 (4.00)	4.72 ± 2.48 (2437)	4.83 ± 2.77 (5.00)	2.56 ± 1.64 (2.00)	5.16 ± 3.45 (4.00)
	1.00 - 64.0 (8389)	1.00 - 21.0 (2437)	1.00 - 27.0 (1848)	1.00 - 15.0 (1974)	1.00 - 64.0 (2130)
O_3 (ppb)	38.1 ± 13.2 (37.0)	45.2 ± 13.4 (44.0)	30.3 ± 13.9 (30.0)	42.2 ± 11.5 (41.0)	32.7 ± 6.00 (32.0)
	1.00 - 104 (8642)	1.00 - 104 (2489)	2.00 - 80.0 (1895)	11.0 - 87.0 (2112)	14.0 - 58.0 (2146)
PM_{10} (μg m^{-3})	42.6 ± 56.3 (32.0)	64.5 ± 92.8 (46.0)	28.0 ± 18.0 (24.0)	35.2 ± 27.7 (27.0)	36.8 ± 28.0 (28.0)
	1.00 - 1458 (8423)	1.00 - 1458 (2464)	1.00 - 150 (1868)	1.00 - 218 (1989)	1.00 - 219 (2102)
SO_2 (ppb)	2.47 ± 2.93 (1.00)	2.39 ± 2.33 (2.00)	1.28 ± 0.68 (1.00)	2.23 ± 1.98 (1.00)	3.67 ± 4.42 (2.00)
	1.00 - 30.0 (7775)	1.00 - 21.0 (2266)	1.00 - 13.0 (1656)	1.00 - 17.0 (1738)	1.00 - 30.0 (2115)
C. Meteorological parameters[d]					
TEMP (°C)[e]	9.04 ± 8.04 (10.6)	7.79 ± 6.69 (9.10)	17.6 ± 2.04 (18.0)	11.0 ± 4.91 (12.6)	-0.28 ± 4.68 (0.20)
	-11.1 - 21.4 (753)	-11.1 - 19.6 (210)	12.8 - 21.4 (183)	-2.90 - 19.4 (180)	-11.1 ± 11.2 (180)
Dew Pt (°C)[e]	-5.38 ± 15.3 (-3.20)	-8.98 ± 13.48 (-7.25)	6.81 ± 9.43 (10.2)	-1.39 ± 10.2 (-1.10)	-17.5 ± 15.7 (-12.1)
	-51.5 - 17.5 (753)	-47.6 - 17.5 (210)	-27.0 - 17.2 (183)	-35.4 ± 13.8 (180)	-51.5 ± 7.20 (180)
WS (m s^{-1})[e]	8.40 ± 4.90 (8.00)	9.81 ± 5.65 (9.00)	7.16 ± 4.04 (6.00)	6.86 ± 3.84 (6.00)	9.57 ± 4.95 (9.00)
	1.00 - 25.0 (750)	1.00 - 25.0 (209)	1.00 - 19.0 (183)	1.00 - 19.0 (180)	2.00 - 25.0 (178)

Note: [a] $Hg^{I]}$ implies the Hg data set after excluding exceptionally high Hg values (i.e., at or above 10 ng m^{-3})
[B] $Hg^{II]}$ is all data at or above 10 ng m^{-3}
[c] $Hg^{III]}$ is selected from results of the best correlation between log (Hg) and log (PM_{10})
[d] measurements were made at 9 AM (daytime) and 9 PM (nighttime)
[e] Acronyms used for meteorological parameters denote: WS = wind speed, TEMP = temperature, Dew Pt = Dew Point

Table 1-6. The mean Hg concentration for each route type of air mass transportation during the entire study period in Gosan during the study period.

A. During entire study period

Altitude	Transport route type[a]							
m	R1	R2	R3	R4	R5	R6	R7	R8
1000	3.35 ± 1.04 (3.02)	3.74 ± 2.02 (3.30)	4.43 ± 1.53 (4.35)	3.39 ± 1.06 (3.26)	5.27 ± 1.38 (5.05)	3.62 ± 1.13 (3.47)	4.73 ± 1.77 (4.21)	3.77 ± 1.12 (3.72)
	1.89 - 12.5	0.10 - 17.9	0.80 - 9.30	1.09 - 8.74	2.04 - 9.16	1.13 - 9.12	1.89 - 10.4	1.54 - 7.58
	(600 (8%)[b])	(3082 (41%))	(1093 (15%))	(591 (8%))	(330 (4%))	(1140 (15%))	(144 (2%))	(470 (6%))
2000	3.07 ± 1.12 (2.77)	3.74 ± 1.81 (3.401)	4.66 ± 1.42 (4.42)	2.87 ± 1.10 (2.91)	5.27 ± 1.38 (5.05)	3.70 ± 1.19 (3.33)	5.55 ± 1.10 (5.40)	3.71 ± 1.15 (3.72)
	0.10 - 7.86	0.45 - 17.9	1.86 - 10.4	1.09 - 5.79	2.04 - 9.16	2.04 - 12.5	3.82 - 8.00	0.80 - 8.00
	(921 (12%))	(3906 (52%))	(1083 (15%))	(214 (3%))	(330 (4%))	(665 (9%))	(94 (1%))	(237 (3%))
3000	3.77 ± 1.43 (3.72)	3.69 ± 1.82 (3.37)	4.17 ± 1.40 (3.86)	3.42 ± 0.72 (3.16)	4.87 ± 1.43 (4.77)	3.78 ± 1.16 (3.40)	5.13 ± 1.34 (5.09)	4.37 ± 0.80 (4.32)
	1.33 - 12.5	0.10 - 17.9	1.86 - 9.75	2.42 - 5.79	2.04 - 9.16	2.04 - 9.12	2.32 - 8.74	2.63 - 6.07
	(907 (12%))	(4618 (62%))	(544 (7%))	(144 (2%))	(379 (5%))	(509 (7%))	(209 (3%))	(140 (2%))

* Definition of each pathway of air mass transport route

- Route type 1: air masses passing from S. China
- Route type 2: air masses passing from N. China
- Route type 3: air masses passing from N. Korea and Land
- Route type 4: passing from E. Sea
- Route type 5: passing from Japan
- Route type 6: only Sea effect (SE and SW Sea)
- Route type 7: passing from Yellow Sea
- Route type 8: local retained

Section 1.

AQM for Hg in urban, regional background, and industrial area

C. Urban industrial area in Korea: Ban Wall Industrial area

Fig. 1-3. A geographical location of the study site in Ansan city, Korea.

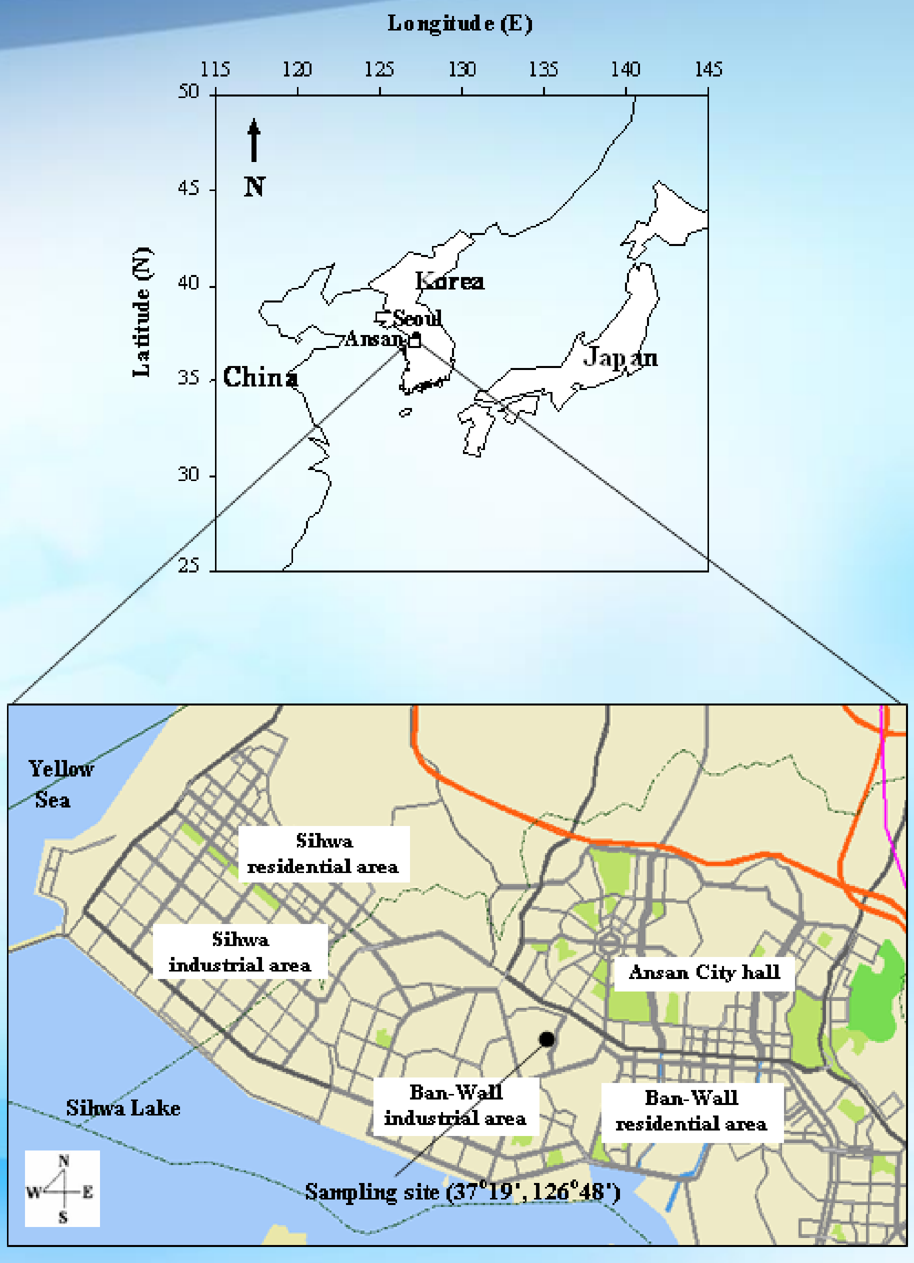


Table 1-7. A statistic summary of Hg monitoring made in Ansan city during spring 2005.

Parameter	(unit)	Mean ± SD (Median)	Range (N)
A. Pollutant species			
Hg	(ng m^{-3})	6.32 ± 8.59 (4.79)	2.32 ~ 181 (1160)
$Hg^{I]}$	(ng m^{-3})	5.06 ± 1.80 (4.60)	2.32 ~ 9.96 (1073)
$Hg^{II]}$	(ng m^{-3})	21.8 ± 26.3 (12.6)	10.1 ~ 181 (87)
SO_2	(ppb)	9.52 ± 11.2 (6.00)	1.00 ~ 134 (1152)
PM_{10}	(mg m^{-3})	114 ± 71.9 (99.0)	9.00 ~ 556 (1160)
O_3	(ppb)	33.3 ± 14.9 (34.0)	3.00 ~ 94.0 (1156)
NO	(ppb)	10.7 ± 17.0 (6.00)	2.00 ~ 211 (1105)
NO_2	(ppb)	23.2 ± 15.3 (20.0)	3.00 ~ 90.0 (1105)
NO_X	(ppb)	33.9 ± 28.8 (27.0)	5.00 ~ 287 (1105)
CO	(ppb)	748 ± 327 (700)	100 ~ 2100 (1156)
B. Meteorological parameters*			
WS	(m s^{-1})	2.35 ± 1.24 (2.20)	0.10 ~ 8.00 (1158)
TEMP	(^{o}C)	14.2 ± 5.29 (14.1)	2.70 ~ 31.5 (1154)

Note: Note: $Hg^{I]}$ implies the Hg data set after excluding exceptionally high Hg values (i.e., at or above 10 ng m^{-3})
$Hg^{II]}$ is all Hg data at or above 10 ng m^{-3}
* Acronyms used for meteorological parameters denote: WS = wind speed, TEMP = temperature

Table 1-8. A comparison of Hg concentration levels between day and night time periods.

Parameter (unit)		Daytime		Nighttime		Results of a Z-statistics test *		
		Mean ± SD (Median)	Range (N)	Mean ± SD (Median)	Range (N)	Z	P	
Hg	($ng\ m^{-3}$)	6.83 ± 5.49 (5.58)	2.46 ~ 64.4 (621)	5.73 ± 11.1 (4.14)	2.32 ~ 181 (539)	2.095	3.615E-02	96.4%
Hg[I]]	($ng\ m^{-3}$)	5.59 ± 1.83 (5.19)	2.46 ~ 9.93 (555)	4.49 ± 1.59 (4.11)	2.32 ~ 9.96 (518)	10.588	0.000E+00	100.0%
Hg[II]]	($ng\ m^{-3}$)	17.2 ± 11.7 (12.0)	10.1 ~ 64.4 (66)	36.3 ± 47.3 (12.9)	10.1 ~ 181 (21)	-1.829	6.736E-02	93.3%
SO_2	(ppb)	9.22 ± 9.18 (7.00)	1.00 ~ 78.0 (616)	9.86 ± 13.1 (6.00)	1.00 ~ 134 (536)	-0.937	3.486E-01	65.1%
PM_{10}	($mg\ m^{-3}$)	117 ± 74.9 (101)	15.0 ~ 556 (623)	112 ± 68.3 (96.0)	9.00 ~ 477 (537)	1.201	2.296E-01	77.0%
O_3	(ppb)	35.8 ± 15.2 (36.0)	4.00 ~ 94.0 (617)	30.3 ± 14.0 (31.0)	3.00 ~ 68.0 (539)	6.349	2.168E-10	100.0%
NO	(ppb)	13.1 ± 18.7 (8.00)	2.00 ~ 211 (589)	7.94 ± 14.2 (3.00)	2.00 ~ 113 (516)	5.143	2.697E-07	100.0%
NO_2	(ppb)	23.5 ± 14.1 (21.0)	3.00 ~ 90 (589)	22.8 ± 16.6 (19.0)	3.00 ~ 80.0 (516)	0.745	4.562E-01	54.4%
NO_X	(ppb)	36.5 ± 29.5 (30)	5.00 ~ 287 (589)	30.8 ± 27.6 (22.0)	5.00 ~ 167 (516)	3.331	8.649E-04	99.9%
CO	(ppb)	730 ± 322 (700)	100 ~ 2100 (617)	768 ± 332 (700)	200 ~ 2000 (539)	-1.975	4.830E-02	95.2%
WS	($m\ s^{-1}$)	2.78 ± 1.23 (2.50)	0.10 ~ 8.00 (630)	1.85 ± 1.03 (1.6)	0.30 ~ 5.90 (528)	13.990	0.000E+00	100.0%
TEMP	(^{o}C)	16.2 ± 5.27 (15.7)	2.70 ~ 31.5 (626)	11.9 ± 4.25 (11.8)	3.00 ~ 25.0 (528)	15.345	0.000E+00	100.0%

1] After excluding exceptionally high Hg values (i.e., at or above 10 ng m^{-3})

Table 1-9. The atmospheric Hg concentrations in ambient air under various environmental settings

Ref. No.	Site	Characteristics of study site	City (Province)/ Country	Study period	TGM ($ng\ m^{-3}$) Mean	SD	Min	Max	N	Reference
I. Industrial area										
North America										
1	Iztapalapa	Industrial (and residential)	Mexico City, Mexico	Fall, 2002	9.81	3.97	2.8	34.2	1148	de la Rosa et al., 2004
2	Tuscaloosa*	Industrial (and urban airshed)	Alabama, USA	Summer, 2002, 2003	4.05	1.28	2	11.8	2424	Gabriel et al., 2005
3	Detroit*	Industrial	Michigan, USA	2003	2.2	1.3	0.5	44.2	3066	Liu et al., 2007
Asia										
4	Ban Wall	Industrial	An San, Korea	Mar. to May, 2005	6.32	8.59	2.32	181	1160	Nguyen et al., 2008
5	Chiba	Industrial	Japan	1991-1996	26		5.6	86	30	Nakagawa and Hiromoto, 1997
6	Iwakuni	Industrial	Japan	1994	44.1		11	77	5	Nakagawa and Hiromoto, 1997
7	Hirosima	Industrial	Japan	1994	24.7		23	39	5	Nakagawa and Hiromoto, 1997
8	Shijingshan	Industrial (suburban)	Beijing, China	Sep. 1998	8.15	3.1	3.2	16.1	2	Liu et al., 2002
9	Guiyang	Industrial (and residential)	Guizhou, China	19-30 April, 2000	8.85	5.5	3.57	146.8	1933	Feng et al., 2003
II. Urban (background or residential) area										
North America										
10	Manhattan*	Urban	New York, USA	Jun. to Nov. 2000	3.84	0.1			1740	Carpi and Chen, 2002
11	Brooklyn*	Urban	New York, USA	Aug. 2000	3.7	0.08			1063	Carpi and Chen, 2002
12	Queens*	Urban	New York, USA	Jul. 2000	2.69	0.03			1270	Carpi and Chen, 2002
13	Waterbury	Urban (center)	Connecticut, USA	Jan. 1997-Dec. 1999	3.76					Chen et al., 2004
14	Toronto*	Urban (downtown)	Ontario, Canada	2001-2002	2.48	2.22	0.39	137	10643	Denis et al., 2006
Europe										
15	Bordeaux	Urban	Bordeaux, France	1995-1996	2.70					Pécheyran et al., 2000
Asia										
15	Tokyo	Urban	Tokyo, Japan	1995	10.9		6.7	29	25	Nakagawa and Hiromoto, 1997
16	Han Nam	Residential	Seoul, Korea	1987-1988	14.4	9.56	4.73	113	2714	Kim and Kim, 2002
17	Han Nam	Residential	Seoul, Korea	1999-2000	5.34	3.92	0.56	80.1	2576	Kim and Kim, 2002
18	Xuanwu	Urban (residential)	Beijing, China	Sep. 1998	10.1	4.85	4.9	25.3		Liu et al., 2002
19	Tiananmen Square	Urban (center)	Beijing, China	Sep. 1998	12.6	3.1	6.7	19.6		Liu et al., 2002
20	Changchun	Urban	China	2001	18.4		4.7	79.6	275	Fang et al., 2004
21	Han Nam	Residential	Seoul, Korea	2004-2009	3.36	1.55	0.01	13.3	1925	Kim et al., 2011

Note: * The results are originally reported as GEM concentration data

Section 2.

Hg emission from diverse man-made activities

A. Hg emission from charcoal products

Pandey S.K., Kim K.-H.*, Kang C.-H., Jung M.-C., Yoon H. (2009)

BBQ charcoal as an important source of mercury emission.

J. Haz. Mat. 162(1), 536-538.

B. Hg emission from oil spill*

Pandey S.K., Kim K.-H.*, Yim U.-H., Jung M.-C., Kang C.-H. (2009)

Airborne mercury pollution from a large oil spill accident on the west coast of Korea.

J. Haz. Mat. 164, 380-384.

C. Hg emission from landfill facilities*

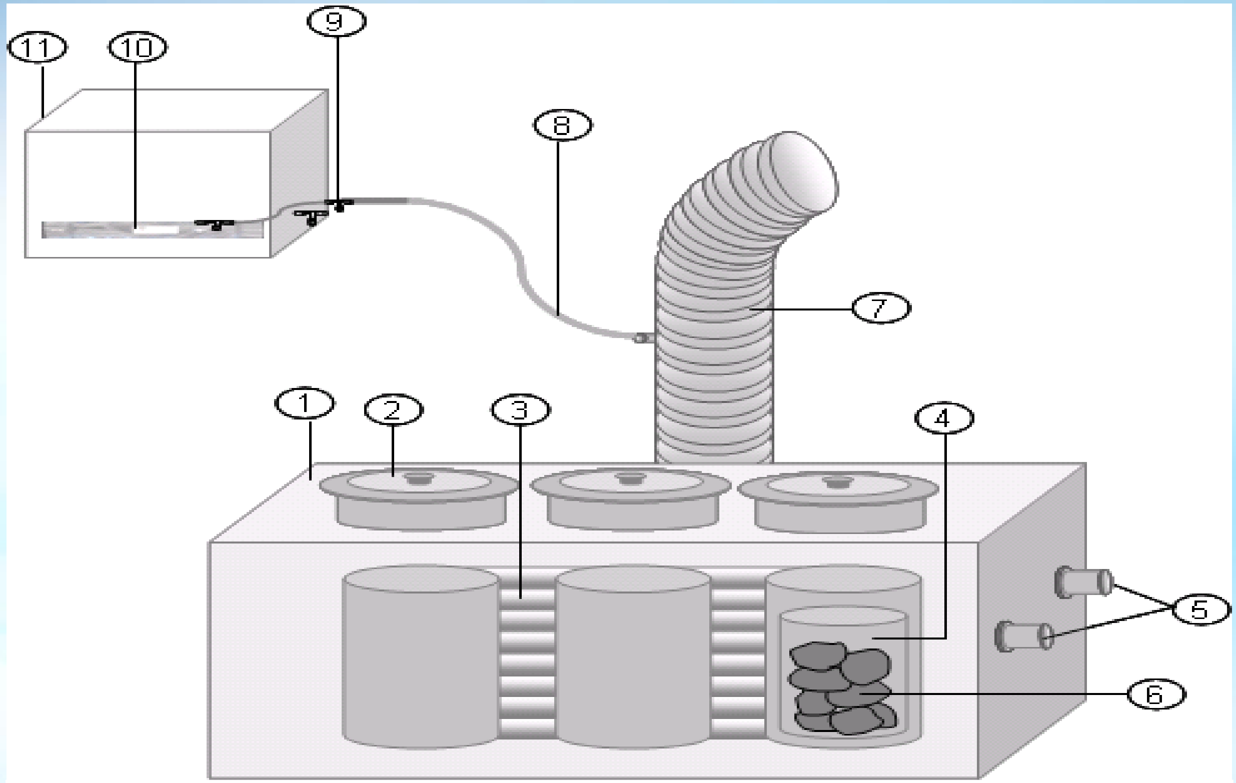
Kim K.-H. and Kim M. Y. (2002)
Mercury emissions as landfill gas from a large-scale abandoned landfill site in Seoul.
Atmospheric Environment 36(31), 4,919-4,928.

Section 2.

Hg emission from diverse man-made activities

A. Hg emission from charcoal products

Fig. 2-1. Schematic diagram of an old style Korean combustor



1. Body of the combustor
2. Cover of the combustion chamber
3. Water pipe
4. Combustion chamber
5. Inlet-outlet of water pipe
6. Burning charcoal
7. Chimney (or smoke stack)
8. Sampling line: connected between chimney and lung sampler
9. Inlet valve
10. Tedlar bag (10 L)
11. Lung sampler

Table 2-1. Basic information about the charcoal samples collected from different countries.

Order	Country of origin	Sample code	Hg concentration ($ng\ m^{-3}$)
1	Korea	K0	496
2	Korea	K1	201
3	Korea	K2	209
4	China	C1	217
5	China	C2	235
6	China	C3	153
7	China	C4	265
8	Malaysia	M1	206
9	Indonesia	I1	415
10	Indonesia	I2	153
11	Indonesia	I3	114
		Mean ± SD (N)	242 ± 115 (11)

Table 2-2. Comparison of mercury emission from various combustion sources.

Order[A]	Combustion sources	Hg [B] (ng m^{-3})	Description
1	Industrial oil-fired boiler	230	Bunker B
2	Coal fired power plant	13660	Anthracite
3	Coal fired power plant	3210	Bituminous (imported)
4	Coal fired power plant	2250	Bituminous (imported)
5	Iron manufaturing plant	9720	Electric furnace
6	Industrial waste incinearator	21250	Industrial hazardous waste
7	Municipal watse incinrator	9460	Municipal waste
8	Automobile exhaust (Gasoline)	3.8-16.8	At driving conditions
9	Automobile exhaust (Diesel)	2.8-8.5	At driving conditions
10	Automobile exhaust (LPG)	20.0-26.9	At driving conditions
11	Coal-fired steam boiler	740	Guizhou Beer Plant, China
12	Charcoal	242[C]	This study

A] All data for 1-7, 8-10, and 11 are selected from Park et al (2008), Won et al (2007), and Tang et al (2007), respectively for the comparison purpose
B] The concentrations for 1-7 and 11 are given for final stack emission that includes reduction with certain air pollution control devices (APCDs) such as: Multi cyclone, electrostatic precipitators (ESP), and Bag filters etc.
C] denotes the mean concentration level derived from all the eleven samples investigated in this study

Table 2-3. Comparison of mercury emission factor from various anthropogenic sources

Order[a]	Type of source	Hg emission factor (g $tonne^{-1}$)
1	Coal-fired	0.238
2	Oil combustion	0.065
3	Cement production	0.1
4	Biomass combustion	0.03-0.1
5	Iron-steel production	0.04
6	Chloro-alkali plants	3.5
7	Crematoria	0.7
8	Charcoal	0.004[b]

a] The data for 1-7 are are based on Wang et al., 2006
b] denotes the mean value derived from all the 11 charcoal samples investigated in this study

Section 2.

Hg emission from diverse man-made activities

B. Hg emission from oil spill accident*

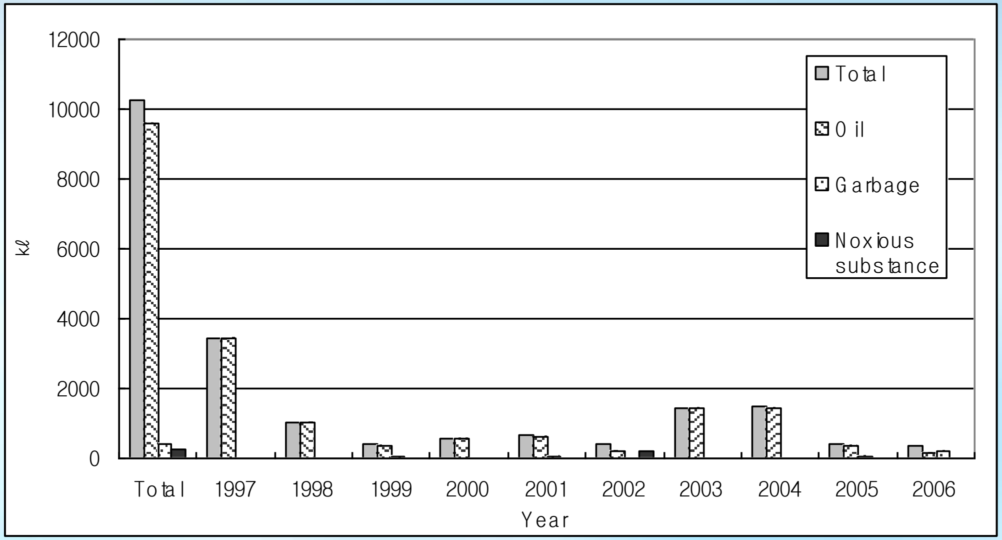
Fig. 2-4. The disaster at Tae-Ahn on 7 Dec. 2007



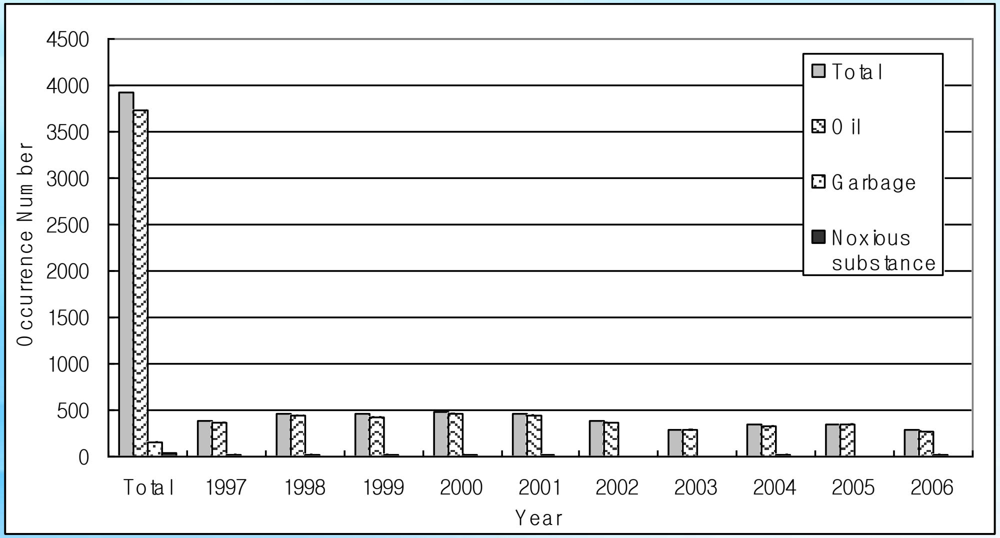

Fig. 2-5. Pictures of Oil spill site at Tae-Ahn beach and clean-up efforts

Fig. 2-6. The statistics of pollutants release due to the maritime accidents in Korea (Ministry of Maritime Affairs and Fisheries (MOMAF), Korea, 2007)

a. Discharged quantity (kℓ)



b. Number of occurrence



Flow of story

Part1. Investigation of Major Odorants at Oil-Spill Site

Part 2. Investigation of Hydrocarbons at Oil-Spill Site

Part 3. Hg Release from Oil-Spill Site

Fig. 2-7. Pictures of air sample collection at Mallipo beach after the oil spill accident (7 Dec. 2007)

– Continued -

Fig. 2-8. Geographical information of oil spill accident site and sampling locations of polluted air

a. Geographical location

b. Sampling sites

Table 2-6. A brief description of sampling campaign at Tae-An oil spillage site [1/2]

Sampling campaign	Order	Sample ID[1)]	Sample collection time	Wind velocity $m\ s^{-1}$	Temperature ℃	Relative humidity %
[A] First phase	1	A-1	14:23	5.3	11	53
(December 11, 2007)	2	A-2	14:28	5.3	11	53
	3	A-3	14:45	4.65	10	60
	4	A-4	14:50	4.65	10	60
	5	A-5	15:15	5.7	11	59
	6	A-6	15:20	5.7	11	59
	7	B-1	14:28	4.2	11	55
	8	B-2	14:33	4.2	11	55
	9	B-3	15:08	4.7	9	62
	10	B-4	15:13	4.7	9	62
	11	B-5	15:35	5.3	10	65
	12	B-6	15:40	5.3	10	65
	13	C-1	16:10	2.5	11	54
	14	C-2	16:15	2.5	11	54
	15	D-1	16:30	1.3	9	58
	16	D-2	16:35	1.3	9	58

Table 2-6. A brief description of sampling campaign at Tae-An oil spillage study [2/2]

Sampling campaign	Order	Sample ID[1]	Sample collection time	Wind velocity $m\ s^{-1}$	Temperature ℃	Relative humidity %
[B] Second phase (January 9, 2008)	1	A-1b	10:10	3.5	6	35
	2	A-2b	10:15	3.5	6	35
	3	A-3b	10:40	3.6	6	42
	4	A-4b	10:45	3.6	6	42
	5	A-5b	11:10	3.6	6	42
	6	A-6b	11:15	3.6	6	42
	7	B-1b	10:15	3.8	6	36
	8	B-2b	10:20	3.8	6	36
	9	B-3b	10:45	2.1	7	45
	10	B-4b	10:50	2.1	7	45
	11	B-5b	11:15	3.9	6	42
	12	B-6b	11:20	3.9	6	42
	13	C-1b	11:47	0.9	6	40
	14	C-2b	11:52	0.9	6	40
	15	D-1b	11:32	1.5	6	40
	16	D-2b	11:37	1.5	6	40

1] Site information: A (Longitude = 126:8:39, Latitude = 36:47:0: Seashore site-first), B Latitude (Longitude = 126:8:45, = 36:47:8: Seashore site-second),C (Longitude = 126:8:44, Latitude = 36:46:52: one block distance apart from site-A), and D (Longitude = 126:8:52, Latitude = 36:47:3: one block distance apart from site-B)

Part1. Investigation of Major Odorants at Oil-Spill Site

Table 2-7. A full list of odorous pollutants investigated initially in this study

Odor Type	Full name	Pollutatnts Short name	Structural formula	Regulation criteria type[1]	Analytical method[2]
A. Carbonyl compounds	Formaldehyde	Form-A	HCHO		DNPH/HPLC
	Acetaldehyde	Acet-A	CH_3CHO	I	
	Acrolein	Acrolein	CH_3=CHCHO		
	Acetone	Acetone	CH_3COCH_3		
	Propionaldehyde	Propion-A	CH_3CHC_2CHO	II	
	crotonaldehyde	Croton-A	CH_3CH=CHCHO		
	Butyraldehyde	Butyr-A	$CH_3CH_2CH_2CHO$	II	
	Benzaldehyde	Benz-A	C_6H_5CHO		
	Isovalerldehyde	Isovaler-A	$(CH_3)_2CHCH_2CHO$	II	
	valealdehyde	Valer-A	$CH_3(CH_2)_3CHO$	II	
	o-Tolualdehyde	o-Tolu-A	$CH_3C_6H_4CHO$		
	m-Tolualdehyde	m-Tolu-A	$CH_3C_6H_4CHO$		
	p-Tolualdehyde	p-Tolu-A	$CH_3C_6H_4CHO$		
B. Reduced S compounds	Hydrogen sulfide	H_2S	H_2S	I	GC/PFPD
	Methyl mercaptan	CH_3SH	CH_3SH	I	
	Dimethyl sulfide	DMS	$(CH_3)_2S$	I	
	Carbon disulfide	CS_2	CS_2		
C. Total and individual VOC	Total hydrocarbon	THC			Micro FID
	Total VOC	TVOC			GC/FID
	Benzene	B	C_6H_6		
	Toluene	T	$C_6H_5CH_3$		
	Ethylbenzene	E	$C_6H_5C_2H_5$		
	m,p-Xylene	MPX	$(CH_3)_2C_6H_4$		
	Styrene	STY	C6H5CH=CH2	I	
	o-Xylene	OX	$(CH_3)_2C_6H_4$		
	Bromobenzene	BB	C_6H_5Br		
	1,3,5-Trimethylbenze	1,3,5-TMB	$(CH_3)_3C_6H_6$		
	1,2,4-Trimethylbenze	1,2,4-TMB	$(CH_3)_3C_6H_7$		
	p-Isopropyltoluene	p-IPT	$C_{10}H_{14}$		
	n-Bultylbenzene	n-BB	$C_{10}H_{14}$		
D. Nitrogeneous	Ammonia	NH_3	NH_3	I	UVS
	Trimethyl amine	TMA	$(CH_3)_3N$	I	GC/NPD

1] Pollutant type: Chemicals of type I and II were designated as criteria odorous pollutants before and after the new regulation started in Feb. 2005 by the Korean Ministry of Environment (KMOE), respectively.
2] Sampling and analytical method: DNPH = sampling by a DNPH-cartridge, HPLC = analysis by HPLC method, GC = gas chromatography, PFPD = pulsed flame photometeric detector, FID = flame ionization detector, NPD = nitrogen p and UVS = UV spectrometer.

Table 2-8. Comparison of pollutant concentrations between the 1st and 2nd campaigns

			2007-12-11	N= 10	2008-01-09	N= 8
			1st exp (after 100 h)		2nd exp (after 30 d)	
	Pollutants	unit	Mean ± SD (median)	Min-max	Mean ± SD (median)	Min-max
A. VOC & TVOC	B	ppb	0.73 ± 1.28 (0.13)	0.13-3.78	0.38 ± 0.14 (0.44)	0.14-0.53
	T		1.54 ± 1.04 (1.19)	0.10-3.73	4.17 ± 3.14 (3.20)	2.20-11.7
	EB		0.33 ± 0.56 (0.11)	0.11-1.89	0.27 ± 0.05 (0.27)	0.20-0.36
	MPX		0.54 ± 0.94 (0.23)	0.040-3.73	0.23 ± 0.05 (0.24)	0.17-0.31
	OX		4.66 ± 7.43 (1.81)	0.079-24.89	0.08	0.08
	STY		0.39 ± 0.74 (0.12)	0.12-2.49	0.15 ± 0.09 (0.12)	0.12-0.38
	BB		0.39 ± 0.50 (0.23)	0.23-1.82	0.24	0.24
	1,3,5-TMB		0.57 ± 1.14 (0.15)	0.15-3.8	0.15	0.15
	1,2,4-TMB		2.09 ± 2.86 (1.49)	0.20-9.53	0.20	0.20
	p-IPT		0.76 ± 1.46 (0.15)	0.15-4.68	0.16	0.16
	n-BB		0.39 ± 0.28 (0.22)	0.22-0.98	0.23	0.23
B. Aldehyde	Form-A	ppb	6.47 ± 6.67 (4.03)	2.62-22.3	42.8 ± 11.2 (41.6)	29.8-59.9
	Acet-A		2.61 ± 0.72 (2.47)	1.72-3.86	4.52 ± 2.58 (4.27)	2.02-8.47
	Acrolein		0.49 ± 0.001 (0.49)	0.49-0.50	0.66	0.66
	Acetone		1.94 ± 0.64 (1.59)	1.43-3.10	2.01 ± 3.55 (0.75)	0.75-10.8
	Propion-A		0.57 ± 0.001	0.57-0.57	0.76	0.76
	Croton-A		0.53	0.53	0.71	0.71
	Butyr-A		0.57	0.57	0.76	0.76
	Benz-A		0.52	0.52	0.71	0.71
	Isovaler-A		0.58	0.58	0.79	0.79
	Valer-A		0.56	0.56	0.87	0.87
	o-Tolu-A		0.55	0.55	1.28	1.28
	m-Tolu-A		0.55	0.55	2.23	2.23
	p-Tolu-A		0.55	0.55	1.74	1.74

– continued -

C. RSC	**H_2S** **CH_3SH** **DMS** CS_2 **DMDS** **SO_2**	ppb	0.10 0.08 0.05 0.34 ± 0.16 (0.28) 0.057 ± 0.08 (0.03) 3.89 ± 1.48 (3.13)	0.10 0.08 0.05 0.17-0.67 0.03-0.3 2.39-6.71	0.16 0.15 2.89 ± 7.91 (0.09) 16.5 ± 3.61 (16.3) 8.19 ± 23.0 (0.06) 0.19	0.16 0.15 0.09-22.5 11.3-22.3 0.06-65.1 0.19
D	**NH_3**	ppb	855 ± 1202 (442)	146-4175	692 ± 272 (681)	309-1200
E	**TMA**	ppb	0.077 ± 0.09 (0.04)	0.04-0.35	0.05 ± 0.07 (0.01)	0.01-0.21
F	**Hg**	ng m^{-3}	16.5 ± 10.4 (13.8)	6.25-36.3	2.69 ± 1.31 (1.78)	1.76-4.82
G	Air Dil'n Sensory	Dil'n Factor	118 ± 86.5 (90)	25-311	43.8 ± 28.5 (37.5)	17.0- 97.0

1] Below detection limit
2] Designated offensive odorants

Part 2. Investigation of Hydrocarbons at Oil-Spill Site

Table 2-9. Operation conditions of GC/MS for the analysis of air samples

GC Model	SHIMADZU GC-2010, JAPAN					
MS Model	SHIMADZU GCMS-QP2010, JAPAN					
Injector	type:	spilt/splitless injector		**Oven program**		
	injector temp.:	250	℃	initial temp:	50	℃
	column flow:	1.2	ml/min	hold time:	5	min
	split ratio:	10:1		temp. rate:	5	℃/min
Column	name:	VOCOL	SUPELCO	final temp.:	200	℃
	diameter:	0.32	mm	hold time:	20	min
	length:	60	m	total time:	55	min
	film thickness:	1.8	㎛			
Detector						
	Ionization mode:	EI (70 eV)		carrier gas:	He	99.999%
	ion sourse temp.:	200	℃			
	interface temp.:	200	℃			
	TIC scan range:	35~250	m/z			

Table 2-10. The results of headspace analysis on the tar samples collected from oil spilled sites: headspace analysis made by SPME with GC

ID	RT (min)	Similarity (%)	Formula	Molecular Weight	Conc. ppb	Chemicals	Hydro Carbon Type	Ref.
T-1	18.2	93.0	C8H18	114	158	n-Octane	paraffinic	= HC-1
T-2	20.9	89.0	C10H23NO	173	248	O-Decylhydroxylamine	others	
T-3	21.3	95.0	C9H20	128	154	3-Methyloctane	paraffinic	
T-4	22.4	96.0	C9H20	128	585	n-Nonane	paraffinic	= HC-3
T-5	23.5	97.0	C8H10	106	188	Xylene	aromatic	= HC-4
T-6	23.7	96.0	C10H22	142	210	3-Methylnonane	paraffinic	
T-7	26.4	97.0	C10H22	142	1,267	n-Decane	paraffinic	= HC-5
T-8	28.3	88.0	C9H12	120	195	1,3,5-Trimethylbenzene	aromatic	
T-9	28.7	92.0	C9H12	120	766	1,3,5-Trimethylbenzene	aromatic	
T-10	28.8	93.0	C10H20	140	195	n-Butylcyclohexane	others	
T-11	29.0	91.0	C11H24	156	319	Decane, 3-methyl-	paraffinic	
T-12	29.7	90.0	C11H22	154	158	1-ethyl-2,2,6-trimethylcyclohexane	others	
T-13	30.0	97.0	C11H24	156	954	n-Undecane	paraffinic	= HC-6
T-14	30.1	94.0	C9H12	120	274	1,2,3-trimethylbenzene	aromatic	
T-15	30.4	89.0	C12H26O	186	203	1-Octanol, 2-butyl-	others	
T-16	30.6	89.0	C10H14	134	224	Diethylbenzene	aromatic	
T-17	30.9	85.0	C50H102O	718	290	1-Pentacontanol	others	
T-18	31.4	91.0	C18H37Cl	288	174	Benzene, 1-methyl-4-propyl-	aromatic	
T-19	31.8	82.0	C10H14	134	203	p-Cymene	aromatic	
T-20	32.4	76.0	C18H37Cl	288	221	1-Chlorooctadecane	paraffinic	
T-21	33.3	96.0	C12H26	170	344	n-Dodecane	paraffinic	= HC-7
T-22	34.9	77.0	C10H14	134	153	Cymol	aromatic	

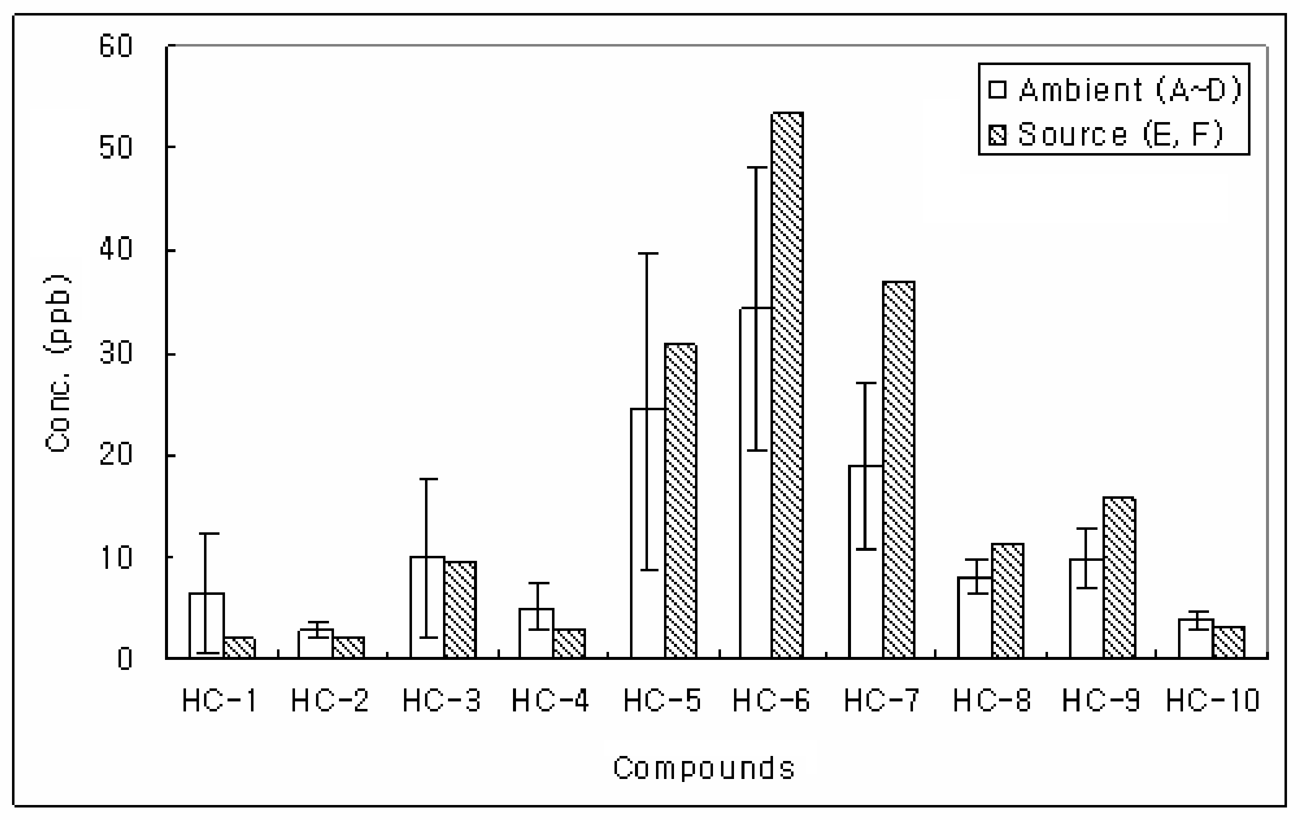
Table 2-11. A list of chemicals determined by GC/MS using ambient air samples collected at Mallipo beach after Oil-Spill accident

Order	Short name	RT (min)	Formula	Molecular weight	Chemicals	Hydro Carbon Type
1	HC-1	18.1	C8H18	114	n-Octane	paraffinic
2	HC-2	19.0	C7H8	92	Toluene	aromatic
3	HC-3	22.4	C9H20	128	n-Nonane	paraffinic
4	HC-4	23.5	C8H10	106	Xylene	aromatic
5	HC-5	26.3	C10H22	142	n-Decane	paraffinic
6	HC-6	30.0	C11H24	156	n-Undecane	paraffinic
7	HC-7	33.3	C12H6	150	n-Dodecane	paraffinic
8	HC-8	35.6	C14H30	198	Dodecane, 4,6-dimethyl-	paraffinic
9	HC-9	36.4	C15H32	212	n-Pentadecane	paraffinic
10	HC-10	37.2	C15H32	212	Dodecane, 2,6,11-trimethyl-	paraffinic

Table 2-12. The analytical results of ambient air samples collected from Mallipo beach area contaminated by the spilled crude oil (ppb)

ID	Compounds	1st					2nd				
		Mean	N	SD	Min	Max	Mean	N	SD	Min	Max
HC-1	n-Octane	4.13	4	5.40	0.47	12.2		0			
HC-2	Toluene	2.69	10	2.13	0.77	8.03	7.37	6	4.10	4.34	15.3
HC-3	n-Nonane	9.83	10	19.7	0.47	65.0		0			
HC-4	Xylene	4.60	10	5.82	0.42	16.7	1.07	5	0.21	0.85	1.39
HC-5	n-Decane	25.6	10	39.2	2.83	133		0			
HC-6	n-Undecane	38.1	10	35.3	11.2	127		0			
HC-7	n-Dodecane	22.5	10	21.6	3.27	67.4		0			
HC-8	Dodecane, 4,6-dimethyl-	8.68	10	4.82	3.45	18.1	1.02	1		1.02	1.02
HC-9	n-Pentadecane	11.1	9	7.29	1.64	22.5		0			
HC-10	Dodecane, 2,6,11-trimethyl-	3.68	10	2.55	1.48	10.1		0			

Fig. 2-9. Comparison of concentration levels of HC from Mallipo beach area (1st campaign)



HC-1	HC-2	HC-3	HC-4	HC-5
n-Octane	Toluene	n-Nonane	Xylene	n-Decane
HC-6	HC-7	HC-8	HC-9	HC-10
n-Undecane	n-Dodecane	Dodecane, 4,6-dimethyl-	n-Pentadecane	Dodecane, 2,6,11-trimethyl-

Part 3. Hg Release from Oil-Spill Site

Fig. 2-10. An instrumentation for the analysis of Hg in air

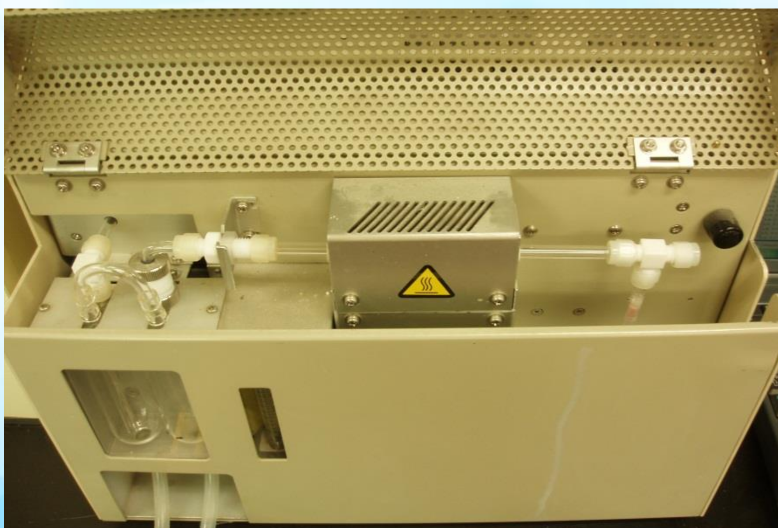
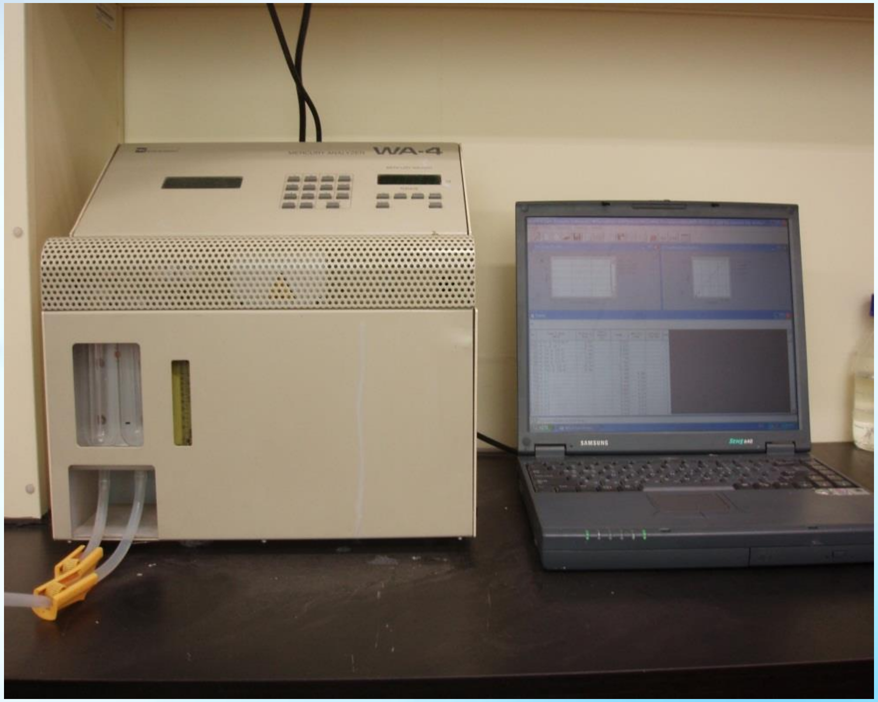


Fig. 2-11. Hg analyzer used in this study



Hg analyzer	WA-4, Nippon Instrument Co., Japan		
Trap	Au-amalgam trap		
Sampling	Flow rate	500	mL min^{-1}
	Total Volumn	1	L
Detector	Wavelength	253.7	nm
Desorption	Temp	700	℃

Table 2-13. A statistics of the oil loss in Hebei Spirit oil spill accident

Order	Company/Location	Amount of oil loaded		Amount of oil released	
		(Barrel)	(Tons)	(Barrel)	(Tons)
1	Iranian heavy	471,193	74,914	33,323	5298
2	Kuwait export	587,411	93,391	33,844	5381
3	UAE upper Zakum	404,292	64,277	10,749	1709
	Total	1,462,896	232,582	77,916	12388

Table 2-14. Comparison of Hg concentration data between two sampling campaigns (ng m^{-3})

Sites	First campaign (Dec. 11, 2007)			Second campaign (Jan. 9, 2008)			Results of a t-statistics		
	Mean	SD	N	Mean	SD	N	t	p	% significance
A	20.4	11.9	6	3.20	1.28	6	2.41E+00	0.0055	99.5
B	12.5	4.41	6	3.29	1.77	6	2.41E+00	0.0011	99.9
C	11.7	2.90	2	1.78	0.03	2	2.41E+00	0.0412	95.9
D	7.34	1.54	2	1.76	0	2	5.12E+00	0.0360	96.4
A and B	16.4	9.85	12	2.90	1.40	12	4.67E+00	0.0001	100
C and D	9.51	3.15	4	1.77	0.03	4	4.15E+00	0.0027	99.7

Fig. 2-12. A comparison of the mean mercury concentration levels between two sampling campaigns:

Results are compared between Hg concentration levels after two days (i.e., December 11, 2007) and after one month (i.e., January 9, 2008) of the oil spillage accident; Dotted lines represent the mean concentrations derived from all the four study sites for aforementioned two different study periods.

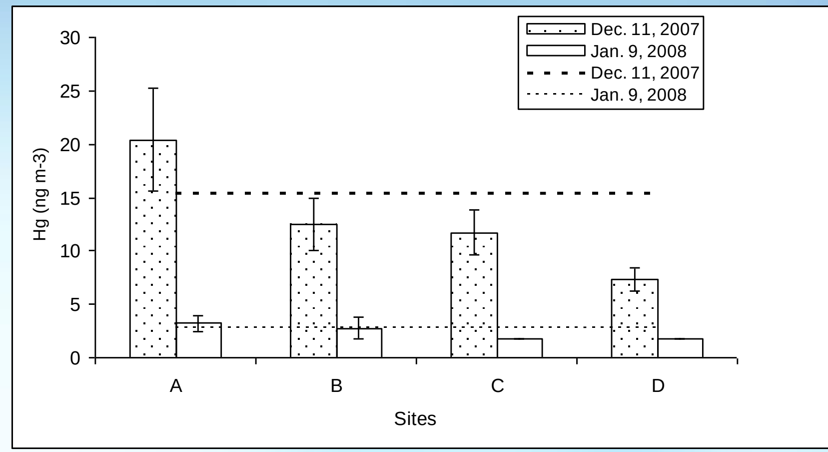
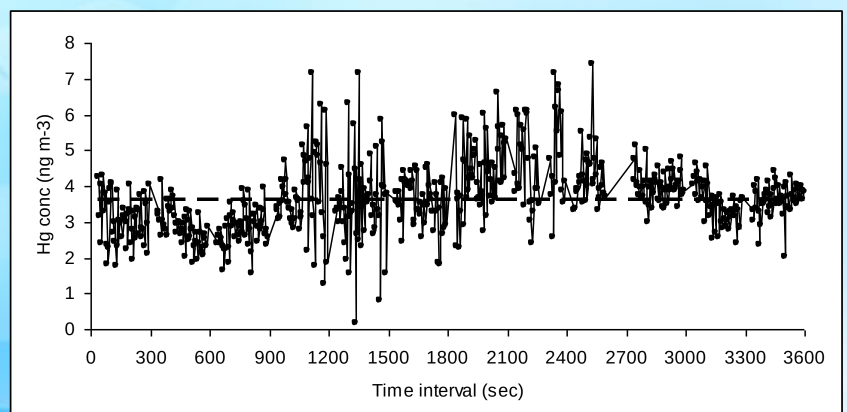


Fig. 2-13. An illustration of continuous Hg concentration data collected over an hour duration on January 9, 2008(from 11:05AM) Dotted line shows the overall mean concentration (i.e., 3.64 ng m^{-3})



Dotted line shows the overall mean concentration (i.e., 3.64 ng m^{-3})

Conclusions

- Pollution of commonly well-known odorants is found to be insignificant in general after oil-spill accident.

- Pollution of long-chain hydrocarbons appear to be fairly recognizable short time after the accident. However, they disappeared through time due in part to active clean-up activities at the site.

- The level of airborne Hg due to oil spill is a significant.

Hg emission from diverse man-made activities

C. Hg emission from landfill facilities*

Section 2.

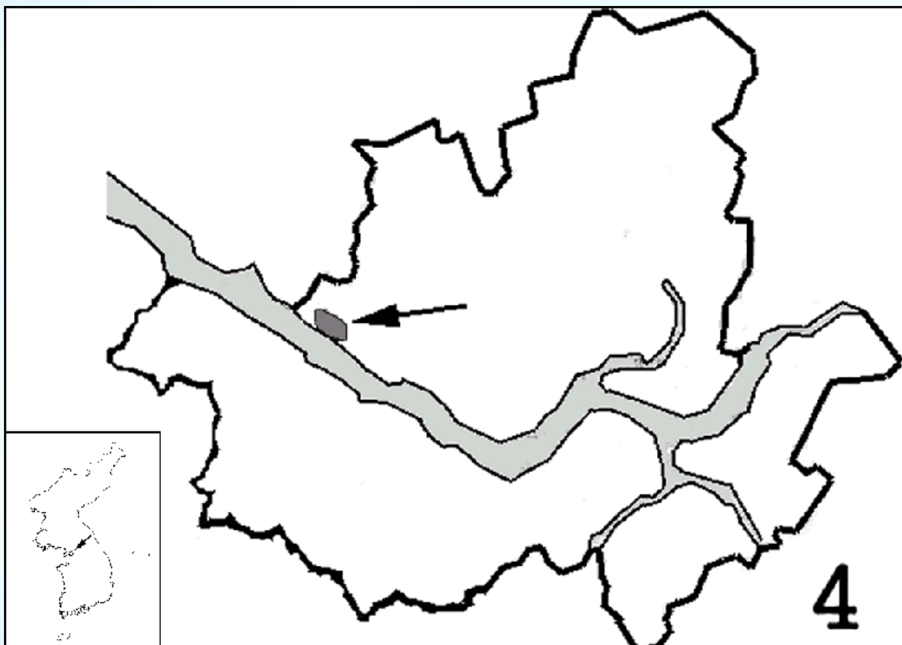
Hg emission from diverse man-made activities

D. Hg emissions from Landfill

Part 1. Previous investigation of LF emission at the capital city

Fig. 2-2. Location of Seoul Metropolitan city and Nan-Ji-Do (NJD) landfill site.

A. City map



B. A detailed map of NJD site. The measurement spot in the sector 1 of NJD.

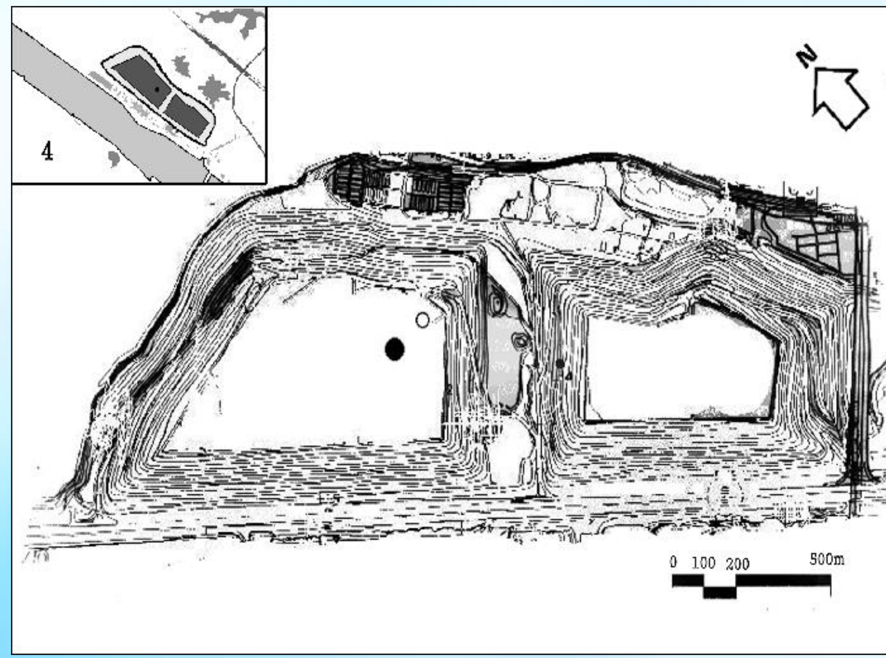


Fig. 2-3. A map showing the locations of ventpipes investigated for the analysis of LFG Hg concentrations in the sector 1 of NJD landfill site. As each ventpipe is allocated with number, its location is depicted by the respective number.

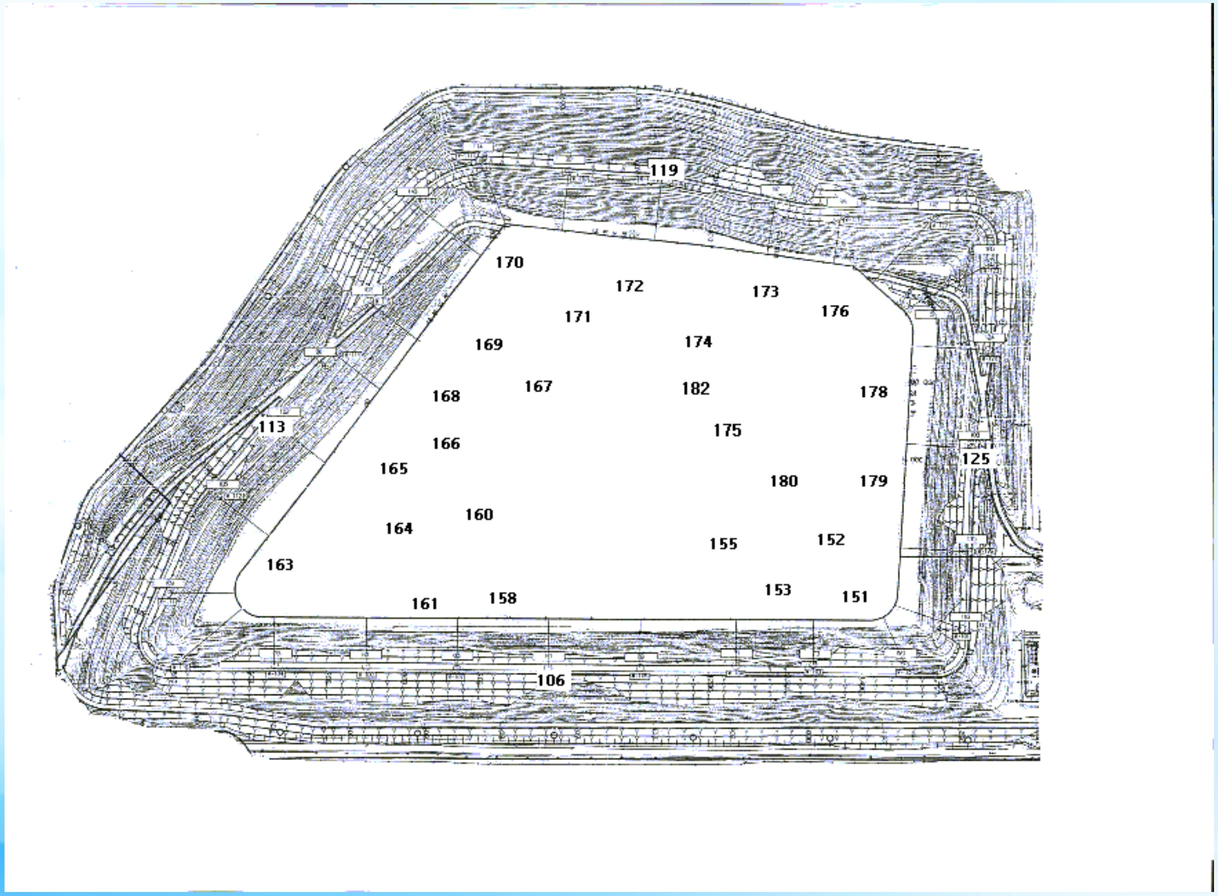


Table 2-4. A statistical summary of vapor-phase Hg concentrations determined from each individual ventpipe located in the sector I of the NJD site.*

Vent No.	Mean	SD	Min	Max	N
(1) Sector 1 - Slope (1S)					
106	1133.50	42.87	1080.00	1182.00	6
113	21.75	5.53	16.80	32.10	6
119	11.90	1.85	9.30	14.70	6
125	36.66	16.79	19.80	60.00	5
(2) Sector 1 - Plain (1P)					
151	869.57	5.03	861.00	873.00	7
152	602.38	17.04	591.00	657.00	13
153	57.65	4.29	51.60	63.90	6
155	4.59	0.52	3.45	4.92	7
158	459.00	36.74	414.00	507.00	6
160	31.00	3.93	28.50	38.70	6
161	307.80	18.02	281.40	330.00	6
163	334.13	10.99	321.00	351.00	8
164	22.00	11.16	13.50	42.30	6
165	2533.33	328.84	2073.00	2952.00	6
166	4.73	0.20	4.38	4.95	6
167	23.28	5.77	18.90	33.30	5
168	2645.50	228.82	2190.00	2799.00	6
169	735.00	13.94	708.00	744.00	6
170	22.80	11.40	6.60	34.80	6
171	13.87	2.06	11.40	16.60	6
172	23.55	3.54	17.70	28.20	6
173	47.83	11.14	26.40	59.70	12
174	32.25	2.99	28.80	36.30	6
175	950.58	97.22	819.00	1125.00	12
176	306.60	97.09	26.40	387.00	11
178	865.00	235.96	378.00	1110	12
179	15.82	3.60	9.30	24.60	23
180	324.05	41.35	273.90	387.00	6
182	25.70	14.20	9.90	42.00	6

*All locations for ventpipes are depicted in Fig 2.

Table 2-5. A statistical summary of Hg and relevant parameters measured simultaneously from the exit of ventpipes at NJD landfill site during Sept./Oct. 2000.

Category	Statistical terms	Hg_{vent} ng m^{-3}	H_2O %	CH_4 %	CO_2 %	EVS* m s^{-1}	T_{vent} ℃	Hg flux mg m^{-2} h^{-1}
Sector 1-Plain (1P)	Mean+SD (Med)	450±715 (57.7)	17.1±6.37 (15.0)	52.3±15.4 (58.3)	25.7±4.40 (26.4)	1.01±0.77 (0.97)	32.5±9.59 (30.2)	2102±3950 (194)
	Min~Max (N)	4.59~2646 (25)	9.62~38.1 (25)	7.2~72.4 (25)	14.3~33.4 (25)	0.21~3.44 (25)	18.8~64.5 (25)	7.23~16904 (25)
Sector 1-Slope (1S)	Mean+SD (Med)	301±555 (29.2)	13.9±2.04 (14.5)	45.4±15.6 (49.3)	35.9±17.0 (29.4)	0.25±0.09 (0.22)	24.9±1.75 (25.4)	246±432 (40.3)
	Min~Max (N)	11.9~1134 (4)	11.2~15.6 (4)	25.2~57.8 (4)	23.7~61.0 (0)	0.17~0.38 (4)	22.6~26.4 (4)	11.1~894 (4)
Sector 2-Plain (2P)	Mean+SD (Med)	569±476 (384)	17.8±2.66 (17.1)	49.9±7.13 (49.0)	30.3±3.18 (28.9)	1.71±1.51 (1.36)	37.0±8.49 (36.2)	5648±9449 (1714)
	Min~Max (N)	66.9~1536 (8)	15.8~23.8 (8)	37.6~58.4 (8)	27.8~37.2 (8)	0.42~5.10 (8)	27.8~53.8 (8)	188~28201 (8)
Sector 2-Slope (2S)	Mean+SD (Med)	235±251 (150)	20.8±4.38 (22.0)	50.2±17.7 (55.6)	27.4±5.46 (29.1)	0.57±0.72 (0.33)	32.9±10.1 (27.5)	332±382 (197)
	Min~Max (N)	81.6~681 (5)	15.1~25.6 (5)	19.8~63.6 (5)	18.3~32.7 (5)	0.12~1.85 (5)	24.8~49.5 (5)	75.0~997 (5)

- denotes "exit ventilation speed" of gases emanating from ventpipes.
- The mean values for the sector 1 (1P and 1S) are derived using individual mean values for each vent, while those of the sector 2 were derived using one-point measurement values for each individual vent.

Part 2. Recent work on the mega LF site: A large-scale LF near the capital area

Fig. 2-14. Location of SUDOGWON landfill site

The 1st landfill site : 1992. 02 start ~ 2000. 10 finish

The 2nd landfill site : 2000.10 start ~ present

Fig. 2-15. Landfill period and capacity

1st landfill

- Site Floor Space : 409(10.000㎡)
- Landfill Area : 251(10.000㎡)
- Landfill Period : 1992.02~2000.10
- Landfill Capacity : 6,400(10.000㎥)

2nd landfill

- Site Floor Space : 409(10.000㎡)
- Landfill Area : 248(10.000㎡)
- Landfill Period : 2000.10~2015.02 expected
- Landfill Capacity : 6,700(10.000㎥)

3rd and 4th landfill

- Site Floor Space
  - 3rd Landfill Site: 394(10.000㎡)
  - 4th Landfill Site: 389(10.000㎡)
- To be filled from the year 2015

Facility complex

- Integrated Environment Research Complex to be built:

Table 2-15. Size of SUDOKWON landfill site

Description	Site size (10,000 m^2)	Landfill size (10,000 m^2)	Landfill capacity (10,000 m^3)	Others
Total	1,979	901	22,800	
1st site	409	251	6,400	
2nd site	409	248	6,700	
3rd site	394	221	9,700	
4th site	389	181		
Others	378	-	-	R&D complex' Anamdo Cistem.

Fig. 2-16. Intake Region Map of landfill site

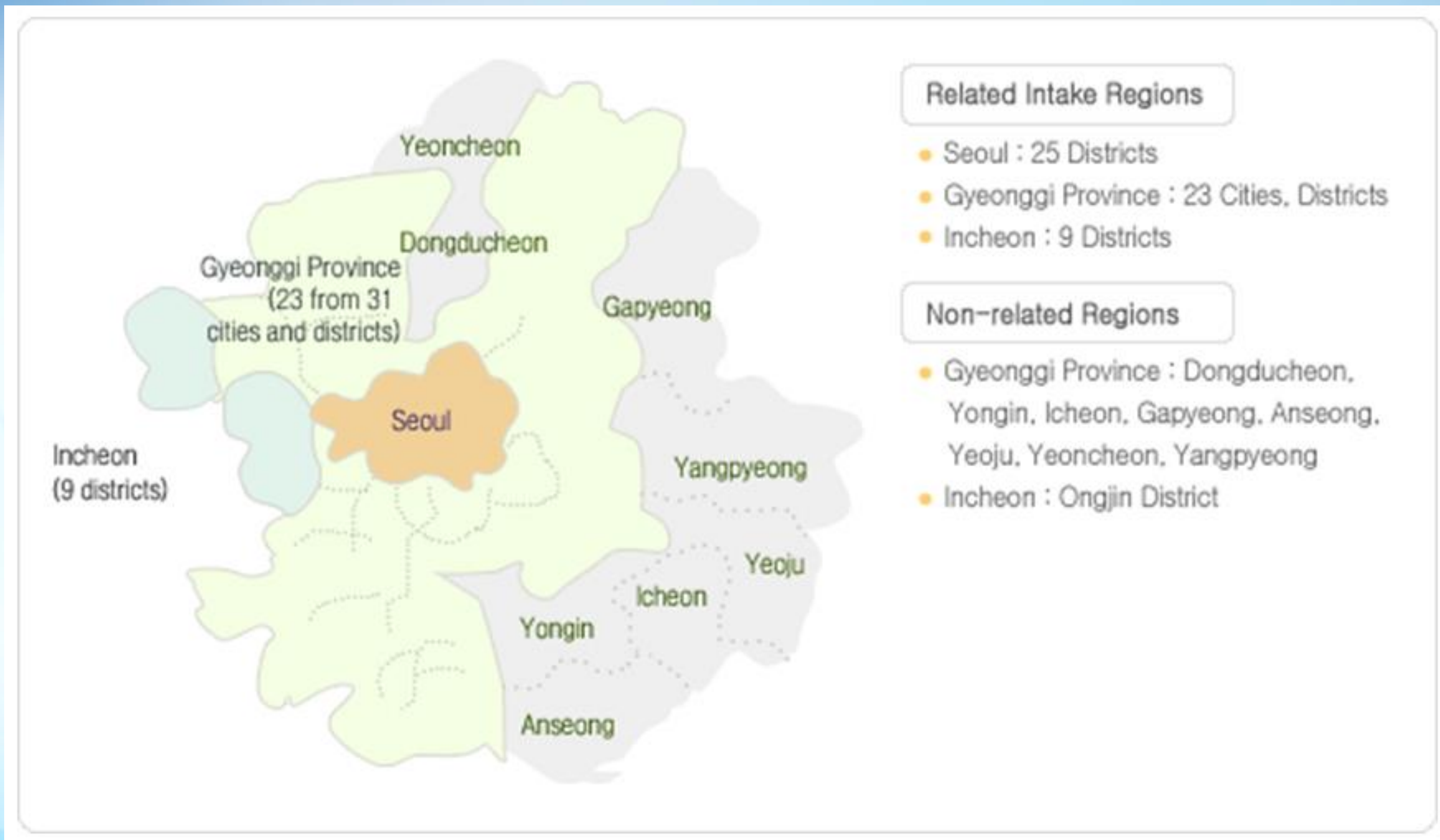


Table 2-16. Types of Waste accepted into landfill site

<table>
<tr><th colspan="5">Type</th></tr>
<tr><td colspan="4" rowspan="4">Municipal waste</td><td>Household</td></tr>
<tr><td>Home industry</td></tr>
<tr><td>Municipal waste from construction site</td></tr>
<tr><td>Briquet ash</td></tr>
<tr><td rowspan="13">Industrial waste</td><td rowspan="10">General industrial site</td><td colspan="2" rowspan="3">Municipal waste from industrial site</td><td>Large site</td></tr>
<tr><td>Small site</td></tr>
<tr><td>Soil</td></tr>
<tr><td rowspan="7">Industrial waste</td><td rowspan="2"></td><td>Sludge</td></tr>
<tr><td>Soil sludge</td></tr>
<tr><td rowspan="5">Inspection needed</td><td>Sewage sludge</td></tr>
<tr><td>Sludge & 4 Types</td></tr>
<tr><td>Synthesized resin</td></tr>
<tr><td>Slag & 17 Types</td></tr>
<tr><td>Burnt ash</td></tr>
<tr><td colspan="3" rowspan="2">Construction waste</td><td>Construction waste</td></tr>
<tr><td>Separated construction waste</td></tr>
<tr><td colspan="3">Designated and infectious waste</td><td>Not accepted</td></tr>
</table>

Fig. 2-17. Operating facilities of landfill site

Leaking Water Treatment Facilities

Highly dense leaking water from the landfill site is safely treated and flow out to minimize environmental damage to surrounding areas. Daily treatment capacity is 6,700㎥(tons) of leaking water

Solidification Facilities

Organic dirt and wastes carried into the Landfill Site are mixed with cement and dried for a certain period to become hardened materials as earth. This is carried to the site again to be used for covering the exposed waste layers so that least bad smell sheds and it substitutes for the covering earth.

Central Incineration Station

Phases	Capacity	Equipment installed	Year of Installation
1st Phase	$340m^3/min$	85 ㎥/min X 4units	Completion: Aug.'96
2st Phase	$340m^3/min$	170㎥/min X 2units	Completion: Nov.'98
Total	$680m^3/min$	6units	

- Continue -

6.5MW Power Plant & 3.38MW Power Plant

Measuring stand is the first gate of the Landfill Site, which is designed for daily measuring about 20,000 tons of wastes carried in from 58 cities, counties and districts of Seoul, Incheon and Kyonggi-do area.

Odor measurement;
Automatic Odor Monitoring Network

Automatic test collector conducts sampling test of the waste carriers at nine random spots.
Precise check-up of waste features completely prevents hazardous wastes from inflowing.

Fig. 2-18. Odor measurement from landfill gas

The existing Automatic Odor Monitoring Network was merely a "spot measurement method" limited to the odor monitoring in its function, and unable to measure various types of odor-generating substances.

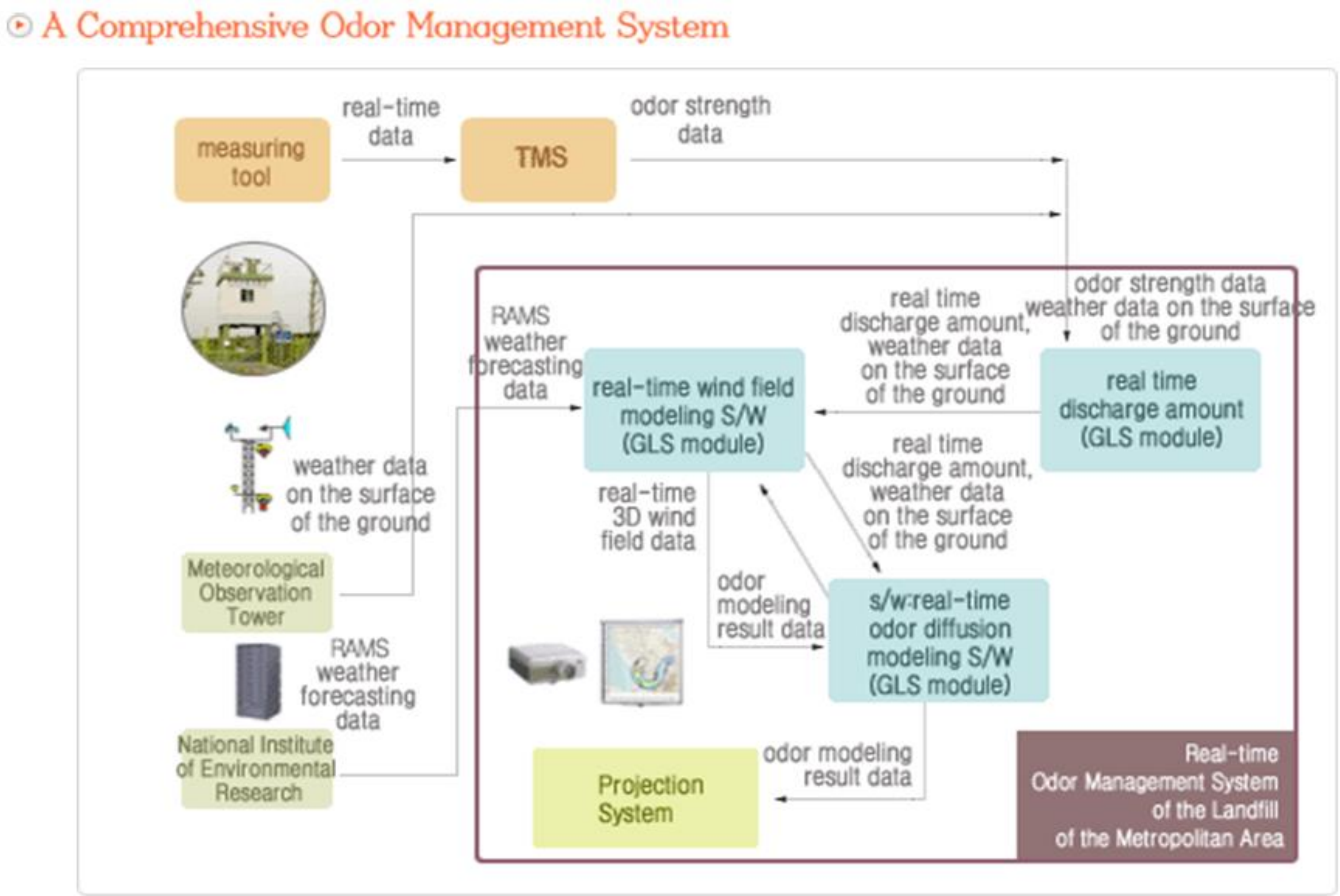


Fig. 2-19. Pictures during sampling on 11th Apr. 2011

(1) Landfill gas for incineration from the 1st landfill site
- Sample code : M-L (Medium-LF)

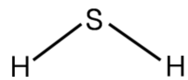
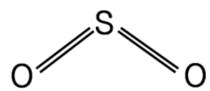
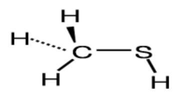
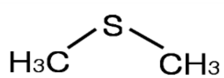
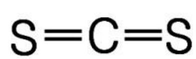
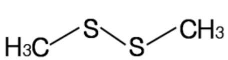
Fig. 2-20. Pictures during sampling on 11th Apr. 2011

(2) Header gas from the 1st and 2nd LF gas collected at 30 minutes interval
– Sample code : H–1 and H–2

Fig. 2-21. Pictures during sampling on 11th Apr. 2011

(3) Blower outlet gas from the 2nd LF gas collected at 30 minutes interval
– Sample code : B-1 and B-2

Table 2-17. Basic information of sulfur compounds and mercury investigated in this study

Order	Short name	Full name	Molecular structure	Molecular weight (g/mol)	CAS Number	Permissible Emission Standard (ppb) [1]	Odor threshold (ppb) [2]
1	H_2S	Hydrogen sulfide		34.1	7783-06-4	60	0.41
2	SO_2	Sulfur dioxide		64.1	7446-09-5	-	870
3	CH_3SH	Methyl mercaptan		48.1	74-93-1	4	0.07
4	DMS	Dimethyl sulfide		62.1	75-18-3	50	3.00
5	CS_2	Carbon disulfide		76.1	75-15-0	-	0.21
6	DMDS	Dimethyl disulfide		94.2	624-92-0	30	2.20
7	Hg	Mercury	-	201	7439-97-6	-	-

[1] Malodor preventer law (KMOE, 2007)
[2] Measurement of odor threshold by triangle odor bag method, Y. Nagata (2003)

Table 2-18. The operational condition of GC/PFPD/TD system for RSC analysis

[1] GC system[a)]

1) Injector			3) PFPD		
Off			detector temp:	200	℃
			air(1) flow:	17	mL/min
			air(2) flow:	10	mL/min
2) Oven			H_2 flow:	14	mL/min
initial temp:	80	℃			
rate:	8	℃/min	4) Column		
final temp:	200	℃	BP-1, SGE (Australia)		
initial hold:	5	min	film thickness:	5	μm
final hold:	5	min	length:	60	m
total time:	25	min	diameter:	0.32	mm

[a)]GC (CP-3800, Varian, USA)

[2] Thermal desorption condition of AS/TD[b)]

cold trap:	Carbopack B+Silica Gel= 1.5 : 2.5 (Volume ratio)				
split ratio:	10:1		trap low:	-15	℃
split flow:	15	mL/min	trap high:	250	℃
hold time:	5	min	flow path temp:	80	℃

[b)]TD (UNITY, Markes International, Ltd., UK)

Table 2-19. Summary of LF composition analysis: reduced sulfur compounds, Hg, CH_4 and D/T ratio

(A) Concentration of all target compounds measured from each sample

Order	Sample code	Information	RSC (ppb)					SO_2	Hg	CH_4	D/T ratio
			H_2S	CH_3SH	DMS	CS_2	DMDS	(ppb)	(ng/m^3)	(%)	(dilution factor)
1	M-L[a)]	Medium (LF)	**341,264**	0.05	0.04	276	0.02	37,159	3.31	24.3	**44,810**
2	H-1[b)]	Header-1	**2,015,314**	**2,568**	**423**	779	0.02	246,922	7.80	14.5	**3,000,000**
3	H-2	Header-2	**2,206,019**	**2,526**	**386**	771	0.02	201,513	21.5	28.9	**3,000,000**
4	B-1[c)]	Blower outlet-1	**2,654,469**	**3,856**	**631**	1,177	0.02	262,995	34.9	38.6	**4,481,410**
5	B-2	Blower outlet-2	**3,700,416**	**3,442**	**537**	1,073	0.02	479,396	28.5	35.6	**1,442,250**

*The underlined part implies below detection limit

Superscripts a, b and c denote old LF, old + new LF and new LF samples, respectively

(B) Mean concentration of header and blower samples

		RSC (ppb)					SO_2	Hg	CH_4	D/T ratio
		H_2S	CH_3SH	DMS	CS_2	DMDS	(ppb)	(ng/m^3)	(%)	(dilution factor)
Header	Mean	2,110,666	2,547	404	775	0.02	224,217	14.6	21.7	3,000,000
(N=2)	SD	134,849	29.4	26.1	5.32	0	32,109	9.66	10.2	0
Blower outlet	Mean	3,177,442	3,649	584	1,125	0.02	371,195	31.7	37.1	2,961,830
(N=2)	SD	739,596	293	66.3	73.4	0	153,019	4.52	2.12	2,149,011
All	Mean	2,183,496	2,478	395	815	0.02	245,597	19.2	28.4	2,393,694
(N=5)	SD	1,219,167	1,498	241	351	0	158,395	13.4	9.57	1,696,782

Fig. 2-22. Comparison of RSC and SO2 concentration in landfill gas samples

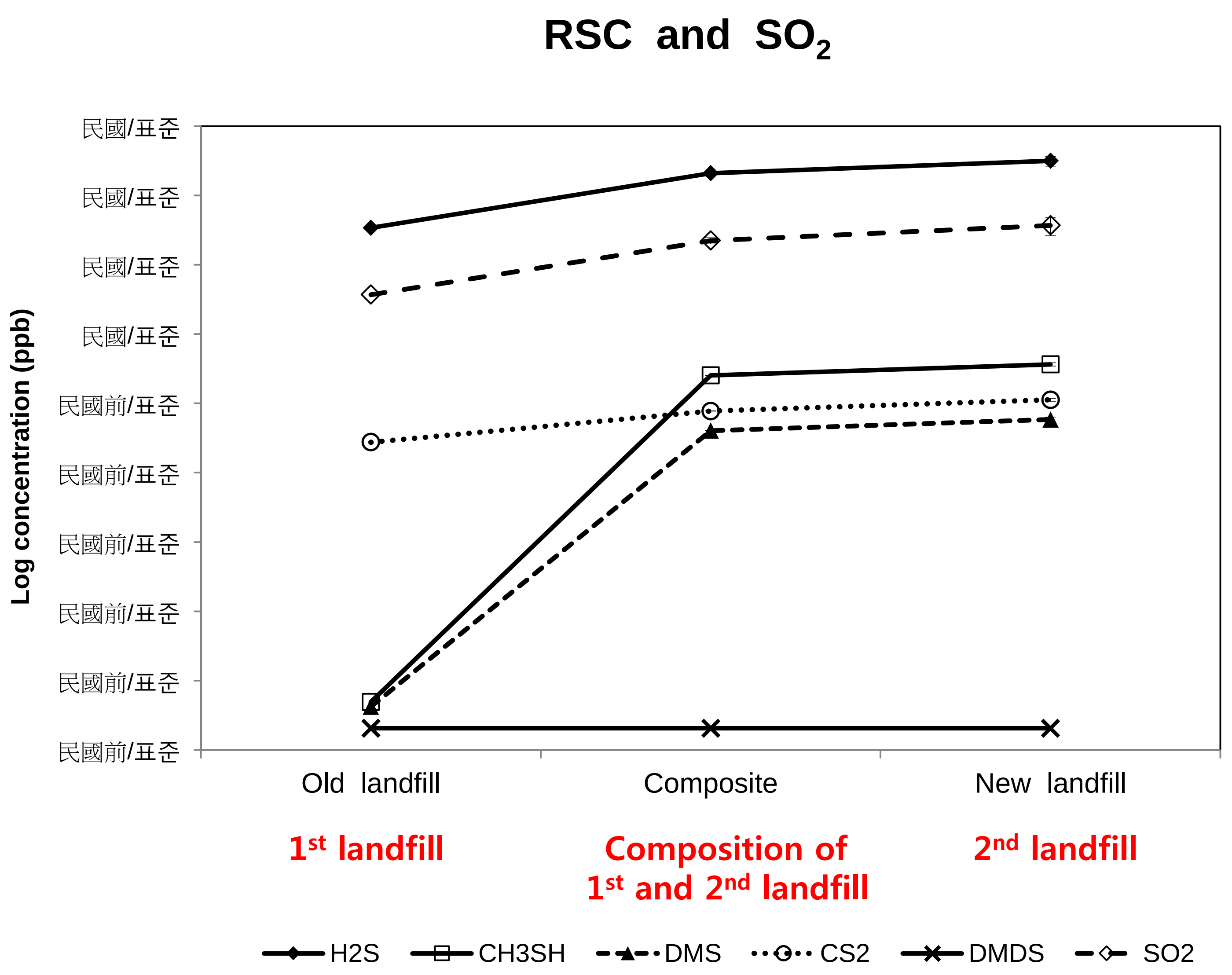


Fig. 2-23. Comparison of RSC concentration levels by odor intensity between each sampling site

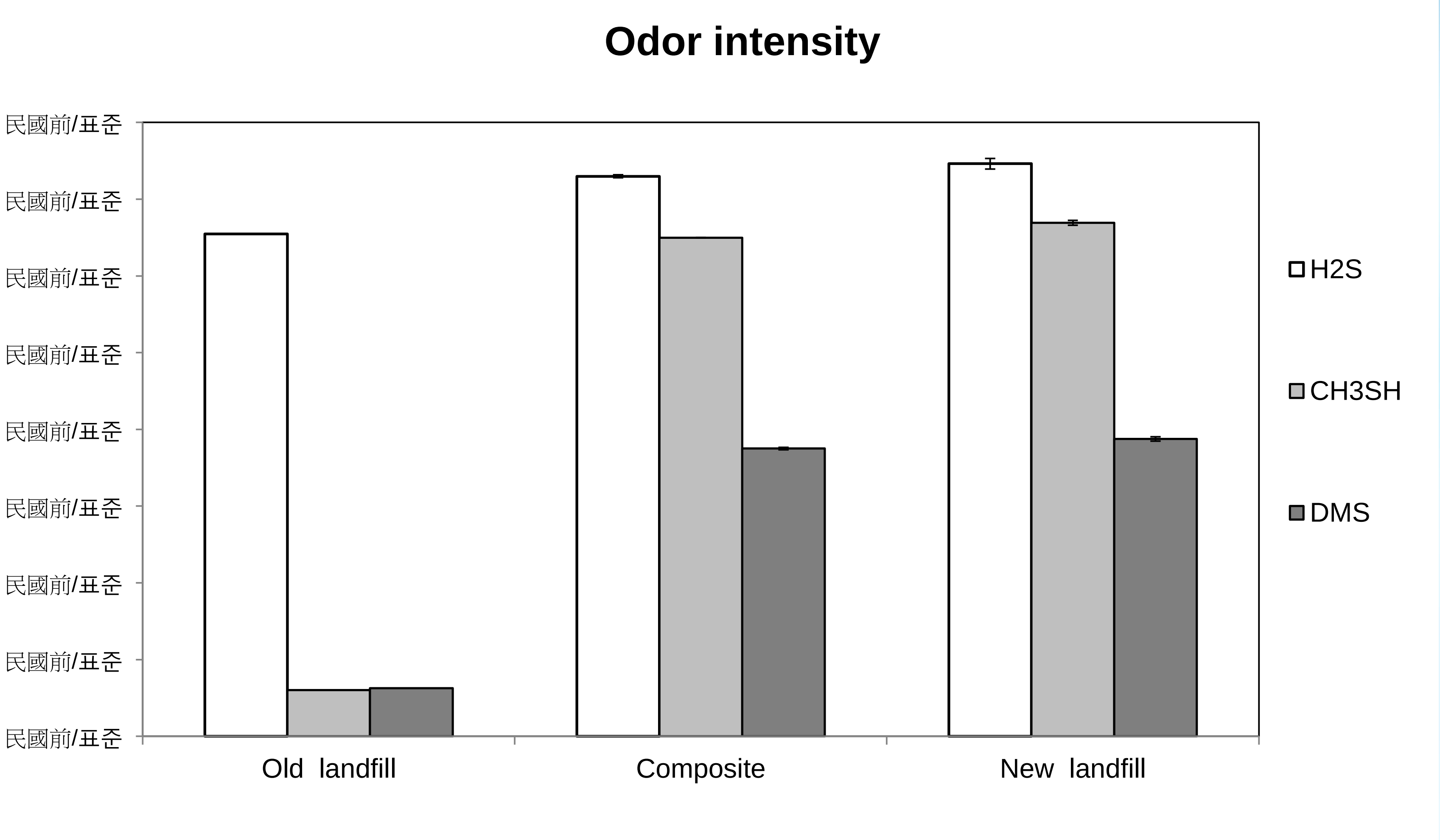


Fig. 2-24. Comparison between gaseous Hg (ng/m3) and CH4 (%) concentration in landfill gas

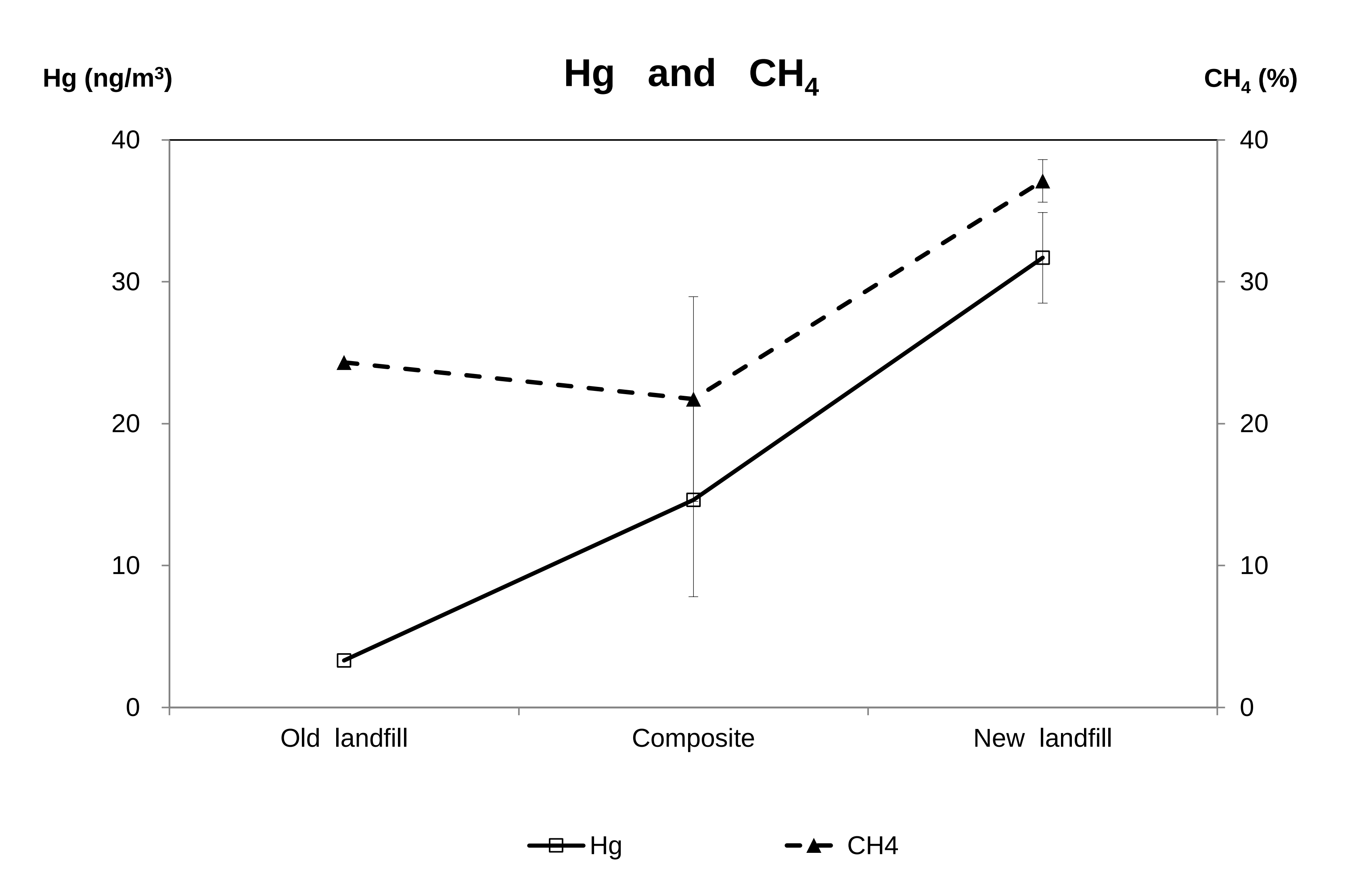


Table 2-20. Comparison of RSC concentrations and relevant parameters between different landfill samples (mean ± SD)

Landfill location	Operation start	Study period	Time passed (years)	RSC (ppb)					Hg (ng/m^3)	CH_4 (%)
				H_2S	CH_3SH	DMS	CS_2	DMDS		
Present study	Old landfill	Apr. 2011	19	341,264	0.05	0.04	276	0.02	3.31	24.3
	New landfill		11	3,177,442 ± 739,596	3,649 ± 293	584 ± 66.3	1,125 ± 73.4	0.02 ± 0	31.7 ± 4.52	37.1 ± 2.12
Dong Hae, Korea[1]	1999	May 2005	6	37,710 ± 57,970	1,634 ± 1,377	819 ± 818	144 ± 166	148 ± 187	NM	NM
Gwang Ju, Korea[2]	1991	Aug. 2003	12	247,757 ± 296,264	1,259 ± 2,872	1,326 ± 2,163	1,245 ± 2,070	8.39 ± 5.01	NM	28.6 ± 13.5
Jeju, Korea	1992	Jul. 2003	11	2,344,358 ± 2,425,295	1,660 ± 538	8,720 ± 11,976	NM	42.1 ± 15.0	NM	31.6 ± 17.9
Dae Gu, Korea	1990	Jan. 2004	14	115,275 ± 118,047	916 ± 378	347 ± 396	691 ± 523	46.4 ± 14.7	3.27 ± 1.23 [3]	59.0 ± 64.0
Florida, USA[4]	NM[a]	NM	NM	1,200,000	1,900	40	30	10	NM	15.4 ~ 44.9
Chun Cheon, Korea[5]	1998	Feb. 2007	9	150,623	185	87.0	NM	DL[b]	NM	NM
Seoul, Korea[6]	1978	Sep. 2000	22	NM	NM	NM	NM	NM	569 ± 476	49.9 ± 7.13
Delaware, USA[7]	1980	Jan. 2003	23	NM	NM	NM	NM	NM	380 ± 440	NM
Minnesota, USA	1967	1993	26	NM	NM	NM	NM	NM	8,600 ± 1,400	NM
Mexico City, Mexico[8]	1998	Sep. 2003	5	95,000 ± 10,000	NM	NM	NM	NM	52.4 ± 15.6	59.3 ± 3.1

[a] Not measured; [b] Below detection limit

[1] Kim, K.-H. (2006); [2] Kim, K.-H. et al. (2005)

[3] Nguyen, H.T. et al. (2008); [4] Lee, S. et al. (2006)

[5] Son, Y.-S. et al. (2007); [6] Kim, K.-H. and Kim, M.-Y. (2002)

[7] Lindberg, S. E. et al. (2005); [8] de la Rosa, D. A. et al. (2006)

Table 2-21. Result of correlation analysis between all parameters analyzed in this study

		H_2S	CH_3SH	DMS	CS_2	SO_2	Hg	CH_4	D/T ratio
H_2S	r	1	0.912*	0.892*	0.913*	0.965**	-0.074	0.549	0.457
	p		0.031	0.042	0.031	0.008	0.906	0.338	0.439
	N	5	5	5	5	5	5	5	5
CH_3SH	r		1	0.998**	0.989**	0.805	0.037	0.522	0.773
	p			0.000	0.001	0.101	0.953	0.367	0.125
	N		5	5	5	5	5	5	5
DMS	r			1	0.989*	0.786	0.068	0.504	0.792
	p				0.001	0.115	0.914	0.386	0.110
	N			5	5	5	5	5	5
CS_2	r				1	0.814	-0.054	0.614	0.726
	p					0.093	0.931	0.270	0.165
	N				5	5	5	5	5
SO_2	r					1	0.008	0.441	0.258
	p						0.990	0.457	0.675
	N					5	5	5	5
Hg	r						1	-0.809	0.203
	p							0.097	0.744
	N						5	5	5
CH_4	r							1	0.246
	p								0.690
	N							5	5
D/T ratio	r								1
	p								
	N								5

* Correlation is significant at 0.05 level
** Correlation is significant at 0.01 level

Thank you