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Supplement of

Assessment of gaseous criteria pollutants in the Bangkok Metropolitan Region, Thailand

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Supplement Material

Section S1: Data Availability and Equipment Calibrations

Data availability:

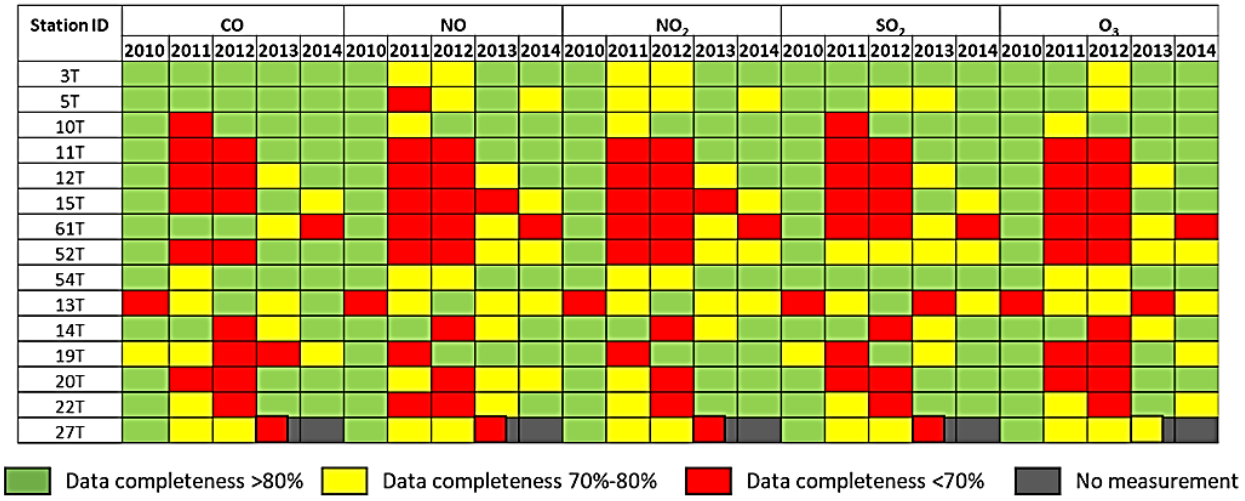

Figure S1: Data availability of gaseous criterial pollutant from the 15 monitoring stations during 2010 to 2014.

Detector details:

SO_2 detectors:

range: 0-500 ppb to 0-20 ppm with auto ranging or better.
lower detection limit: < 1 ppb
precision: 0.5 ppb or < 1% of reading or better
zero drift: < 1 ppb/24-hour
span drift: < 1% of reading/ 24-hour

NO_x detectors:

range: 0-500 ppb to 0-20 ppm with auto ranging or better.
lower detection limit: < 0.5 ppb
precision: 0.5 ppb or < 1% of reading or better
zero drift: < 1 ppb/24-hour
span drift: < 1% of full scale/ 24-hour

CO detectors:

range: 0-50 ppm to 0-200 ppm with auto ranging or better.
lower detection limit: < 0.05 ppm
precision: < 1% of reading or better
zero drift: < 0.1 ppm/24-hour
span drift: < 1% of reading/ 24-hour

O_3 detectors:

range: 0-500 ppb to 0-10 ppm with auto ranging or better.
lower detection limit: < 0.6 ppb
precision: 1% of reading or better
zero drift: < 1 ppb/24-hour
span drift: < 1% of reading/ 24-hour

Detector/ data loggers/ air inlets calibration/ maintenance:

single point calibration for detectors: every 15 days
multi-point calibration with 3 span levels (20 %, 40 % and 80 %): every 90 days
mass flow adjustments: every 90 days
molybdenum converter for NO_2 detectors: at least 4 times in 730 days
zero air generators: at least 4 times in 730 days
data loggers maintenance: every 15 days
air inlets maintenance: every 15 days

Acceptance data criteria:

1. Span drifts
   span drift: < ± 10 % of full scale for NO_2, SO_2, CO detectors
   span drift: < ± 7 % of full scale O_3 detectors
2. Zero checks
   zero drift: < ± 5 ppb for NO_2, SO_2 and O_3 detectors
   zero drift: < ± 0.4 ppm for CO detectors

Section B: Maximum and Average Concentrations of Gaseous Pollutants

Table S1: Statistical analysis of the concentrations of gaseous pollutants from the three monitoring station types during 2010 to 2014.

Monitoring station type	Maximum concentration** (ppb)					Average concentration*** (ppb)				
	CO*	NO	NO_2	SO_2	O_3	CO*	NO	NO_2	SO_2	O_3
BKK sites	5.7±0.9	419.2±236.0	120.5±14.8	29.8±5.3	153.7±10.8	0.7±0.2	16.3±7.8	20.2±5.7	3.3±1.0	18.6±2.3
Roadside sites	8.0±0.4	683.0±396.0	166.0±19.8	26.0±5.7	130.5±14.8	1.0±0.1	60.5±42.7	30.9±8.1	2.6±1.0	13.9±8.6
BKK suburb sites	4.5±1.2	297.5±70.6	115.8±15.8	72.2±58.3	163.0±18.5	0.7±0.1	11.4±3.8	16.1±2.6	4.0±2.3	21.4±3.3

Note: * in ppm, ** 5-year average maximum concentrations ± 1 standard deviation, *** 5-year average concentration ± 1 standard deviation

Section S3: Seasonal Variations of Gaseous Criteria Pollutants

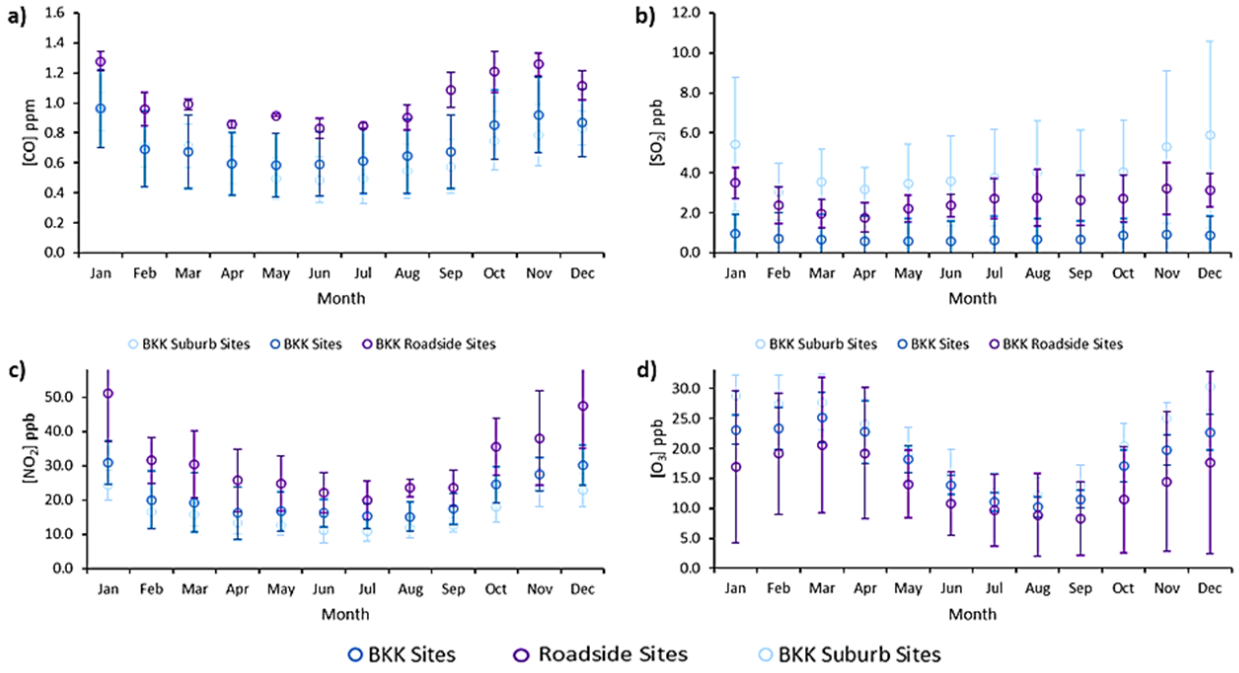

Figure S2: Seasonal variations of a) CO b) SO_2 c) NO_2 and d) O_3 from the three monitoring station types during 2010 to 2014. Dots reveal monthly average concentrations; and vertical bars reveal ±1 standard deviations of the concentrations.

Section S4: Inter-annual Variations of Gaseous Pollutants

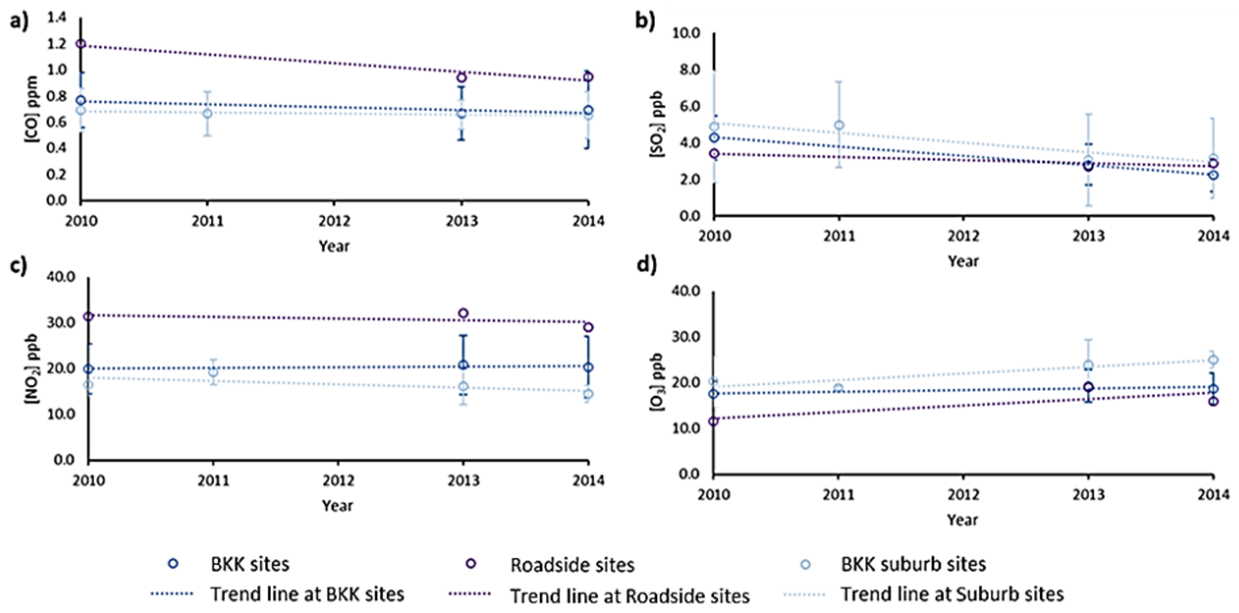

Figure S3: Inter-annual variations of a) CO b) SO_2 c) NO_2 and d) O_3 from the three monitoring station types during 2010 to 2014. Dots reveal yearly average concentrations; and vertical bars reveal ±1 standard deviations of the concentrations.

Section S5: Season Wise Distributions of the Diurnal Variations of Gaseous Criteria Pollutants

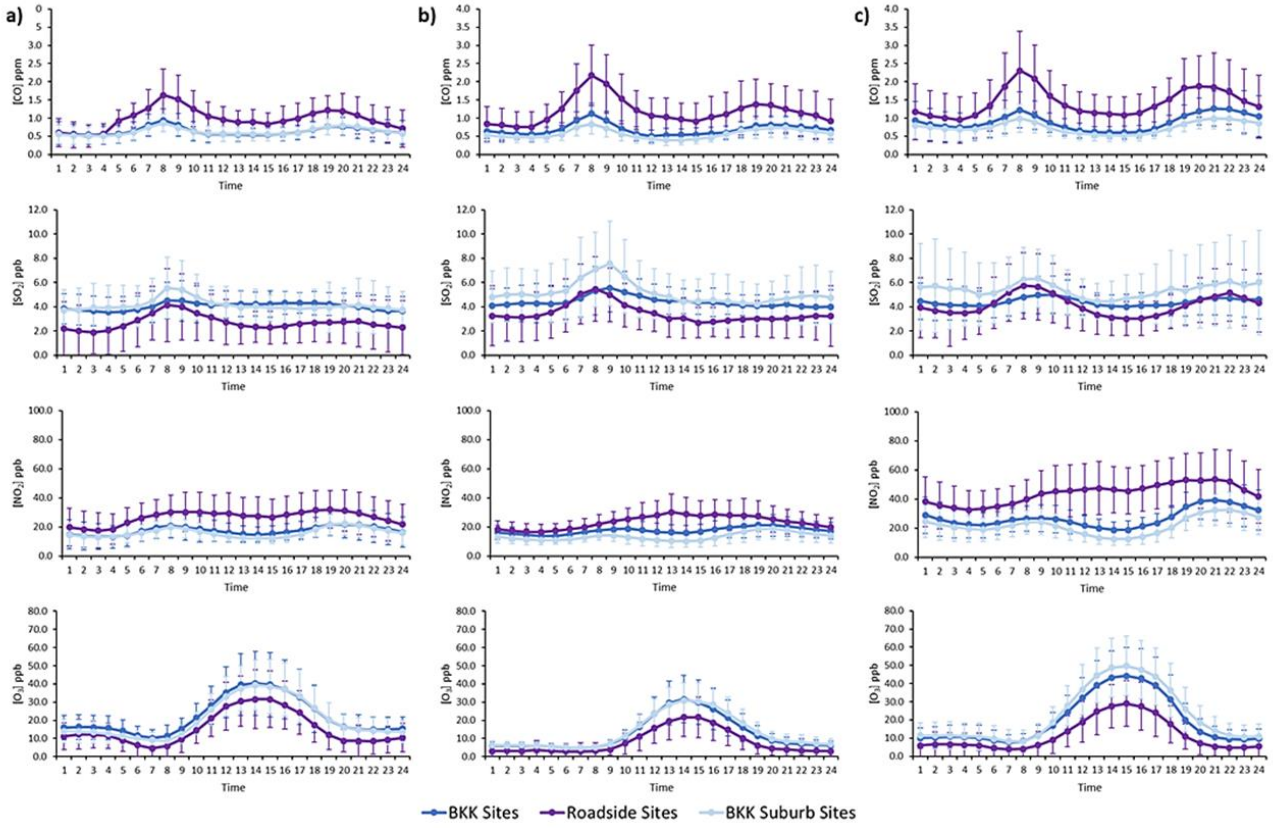

Figure S4: Season wise distributions of the diurnal variations of CO, SO_2, NO_2 and O_3 during local summer (column a)), wet season (column b)) and local winter (column c)) at the three monitoring station types. Vertical bars reveal ±1 standard deviations of the concentrations

Section F: Chemical Rate Coefficients

Table S2: Statistical analysis of the chemical rate coefficients (j_1 and k_3) based on an observational analysis during dry seasons at BKK sites, roadside and BKK suburb sites, 2010 to 2014.; and statistical analysis of j_1 based on a modeling analysis at the latitude and the longitude of 13.7 ˚N, 100.5 ˚E in a dry season, 2010.

Sites	**Rate coefficient**											
	***j*1**						***k*3**					
	min^{-1}			**s^{-1}**			**ppm^{-1} min^{-1}**			**cm^3 molecule^{-1} s^{-1}**		
	Max	**Min**	**Average**	**Max**	**Min**	**Average**	**Max**	**Min**	**Average**	**Max**	**Min**	**Average**
Based on observation*												
BKK	0.95	0.12	0.74±0.2	0.016	0.004	0.008±0.035	30.9	28.6	29.8±0.7	2.06e^{-14}	1.99e^{-14}	2.02e^{-14}±2.01e^{-16}
Roadside	0.90	0.36	0.64±0.3	0.015	0.011	0.013±0.002	30.6	28.3	29.7	2.03e^{-14}	2.03e^{-14}	2.03e^{-14}
BKK suburb	1.22	0.34	0.55±0.3	0.022	0.007	0.010±0.004	30.9	28.8	29.8±0.7	2.04e^{-14}	2.01e^{-14}	2.03e^{-14}±1.34e^{-16}
Based on modeling**												
13.7 ˚N, 100.5 ˚E						0.021±0.002						

Section G: Correlations between CO and NO_x; and $SO_2$and NO_x

Table S3: Correlations between CO and NO_x; and SO_2 and NO_x at BKK sites, roadside sites and suburb sites, during 2010 to 2014; together with ±1 standard deviation.

Station type	Station ID	Correlation	
		CO and NO_x	**SO_2 and NO_x**
BKK sites	**3T**	0.76	0.34
	5T	0.56	0.37
	10T	0.76	0.36
	11T	0.68	0.33
	12T	0.61	0.26
	15T	0.64	0.29
	61T	0.85	0.28
	Average	0.69±0.10	0.32±0.04
Roadside sites	**52T**	0.73	0.49
	54T	0.72	0.56
	Average	0.72	0.53
Suburb sites	**13T**	0.92	0.32
	14T	0.64	0.11
	19T	0.47	0.39
	20T	0.55	0.21
	22T	0.71	0.27
	27T*	0.77	0.53
	Average	0.68±0.16	0.30±0.15

Note: *the correlations are calculated based observations during 2010 to 2013

Section S8: AQI O_3 Calculation

To calculate AQI for O_3, a midpoint of 8-hour average of O_3 concentration is needed. The midpoint of a specific hour is calculated from the average of hourly O_3 concentration of the previous four hours, at the given hour and the following three hours (Fig. V). To get a valid calculation, at least 6 of 8 records (75%), are needed. Calculated AQI values are compared with the AQI table (Fig. VI) (US.EPA, 2017a, 2017b)

Hours	1	2	3	4	5	6	7	8	9
$[O_3]_{hourly}$						*			
		The previous 4 hours				AQI	The following 3 hours		

Figure S5: The calculation of a midpoint of AQI for O_3 (modified from US.EPA, 2017a)

Air Quality Index (0-500)	Who Needs to be Concerned?	What Should I Do?
Good (0-50)	It's a great day to be active outside.	
Moderate (51-100)	Some people who may be unusually sensitive to ozone.	**Unusually sensitive people:** *Consider reducing* prolonged or heavy outdoor exertion. Watch for symptoms such as coughing or shortness of breath. These are signs to take it a little easier. **Everyone else:** It's a good day to be active outside.
Unhealthy for Sensitive Groups (101-150)	Sensitive groups include **people with lung disease such as asthma, older adults, children and teenagers, and people who are active outdoors.**	**Sensitive groups:** *Reduce* prolonged or heavy outdoor exertion. Take more breaks, do less intense activities. Watch for symptoms such as coughing or shortness of breath. Schedule outdoor activities in the morning when ozone is lower. **People with asthma** should follow their asthma action plans and keep quick relief medicine handy.
Unhealthy (151 to 200)	**Everyone**	**Sensitive groups:** *Avoid* prolonged or heavy outdoor exertion. Schedule outdoor activities in the morning when ozone is lower. Consider moving activities indoors. **People with asthma**, keep quick-relief medicine handy. **Everyone else:** *Reduce* prolonged or heavy outdoor exertion. Take more breaks, do less intense activities. Schedule outdoor activities in the morning when ozone is lower.
Very Unhealthy (201-300)	**Everyone**	**Sensitive groups:** *Avoid all* physical activity outdoors. Move activities indoors or reschedule to a time when air quality is better. **People with asthma,** keep quick-relief medicine handy. **Everyone else:** *Avoid* prolonged or heavy outdoor exertion. Schedule outdoor activities in the morning when ozone is lower. Consider moving activities indoors.
Hazardous (301-500)	**Everyone**	**Everyone:** *Avoid all* physical activity outdoors.

Figure S6: The AQI (US.EPA, 2017b)