Supplementary Material

Aerosol Particle and Black Carbon Emission Factors of Vehicular Fleet in Manila, Philippines

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Table S1. Overview of pollutant concentrations on the curbside (Ks) and background (Bg) level at Taft Avenue, Manila, Philippines using merged PNSDs of MPSS and APS.

Pollutant	Unit	Site	Average	Ks/Bg Ratio	Median	SD	CoV
eBC	$\mu g\ m^{-3}$	Ks	28.8	2.74	27.3	7.40	0.26
eBC	$\mu g\ m^{-3}$	Bg	10.5		9.70	3.70	0.35
PM_1	$\mu g\ m^{-3}$	Ks	33.0	3.55	31.0	10.7	0.32
PM_1	$\mu g\ m^{-3}$	Bg	9.30		8.50	3.32	0.36
$PM_{2.5}$	$\mu g\ m^{-3}$	Ks	41.1	2.92	38.7	11.9	0.29
$PM_{2.5}$	$\mu g\ m^{-3}$	Bg	14.1		13.5	3.96	0.28
PM_{10}	$\mu g\ m^{-3}$	Ks	60.0	2.55	55.1	16.2	0.27
PM_{10}	$\mu g\ m^{-3}$	Bg	23.5		23.0	5.40	0.23
PN Bin1	particles cm^{-3}	Ks	39,700	4.00	38,500	8150	0.21
PN Bin1	particles cm^{-3}	Bg	9940		9680	1850	0.19
PN Bin2	particles cm^{-3}	Ks	26,300	3.20	24,500	7120	0.27
PN Bin2	particles cm^{-3}	Bg	8220		8430	2390	0.29
PN Bin3	particles cm^{-3}	Ks	12,400	3.51	11,500	3950	0.32
PN Bin3	particles cm^{-3}	Bg	3530		3400	1300	0.37
PN Bin4	particles cm^{-3}	Ks	93.0	6.20	84.0	34.0	0.37
PN Bin4	particles cm^{-3}	Bg	15.0		13.0	4.90	0.33
$PN_{<1000\ nm}$	particles cm^{-3}	Ks	78,500	3.05	74,600	18,500	0.24
$PA_{<1000\ nm}$	$\mu m^2\ m^{-3}$	Ks	756	3.11	703	233	0.31
$PV_{<1000\ nm}$	$\mu m^3\ m^{-3}$	Ks	18.3	3.52	17.1	6.00	0.33
$PN_{<1000\ nm}$	particles cm^{-3}	Bg	25,700		25,400	5840	0.23
$PA_{<1000\ nm}$	$\mu m^2\ m^{-3}$	Bg	243		228	82	0.34
$PV_{<1000\ nm}$	$\mu m^3\ m^{-3}$	Bg	5.20		4.71	1.84	0.35

SD: Standard Deviation; CoV: Coefficient of Variation; Ks: curbside; Bg: Background; Bin1: Nucleation mode (10–20 nm); Bin2: Young Aitken mode (20–60 nm); Bin3: Aitken and Lower Accumulation mode (60–300 nm); Bin4: Accumulation mode (300–800 nm); PN, PA, PV: Particle number, surface area, and volume for particles $D_p < 1000$ nm.

Table S2. Meteorological Observation. Summary of meteorological conditions at Taft Avenue from 18 May–10 June, 2015. Rainy days were excluded in the data analysis.

Site		WS (m/s)	Temperature (°C)	RH (%)	Global Radiation (W/m²)	Precipitation (mm/h)
	mean	0.80	30.7	69.4	308	0.30
	median	0.66	30.7	70.0	149	0.00
Taft Ave.	SD	0.47	1.81	7.75	296	5.65
	max	4.80	35.1	92.0	1000	320
	min	0.01	24.4	45.0	0.00	0.00

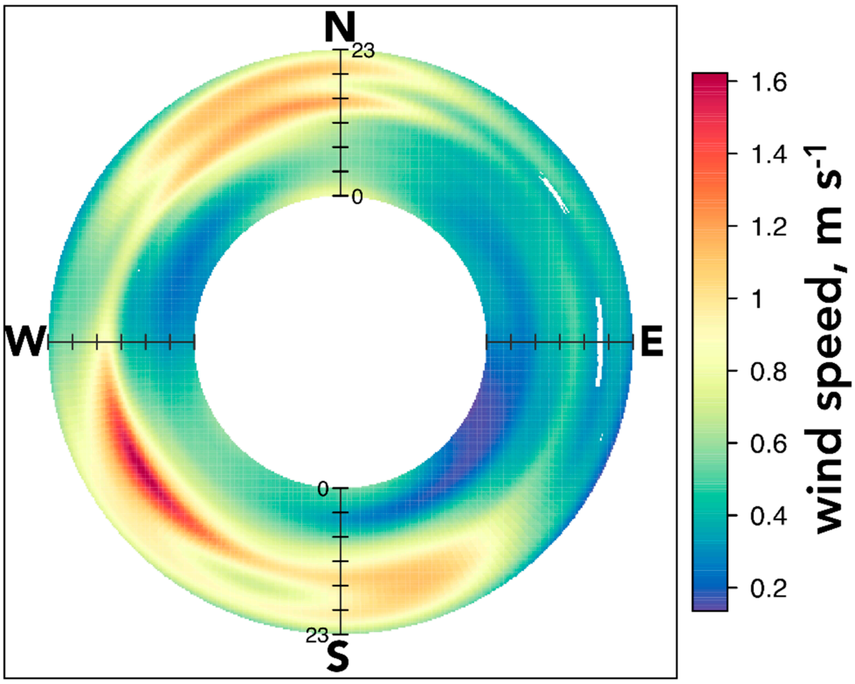

Figure S1. Variation of observed wind speed and direction at the measurement site.

Gaps in the data (Fig. S1) are colored with white. Red color indicates high wind speeds. The plot also includes the hours of day when the maximum and minimum values were recorded. For example, during midday highest wind speed comes from Southwest wind direction.

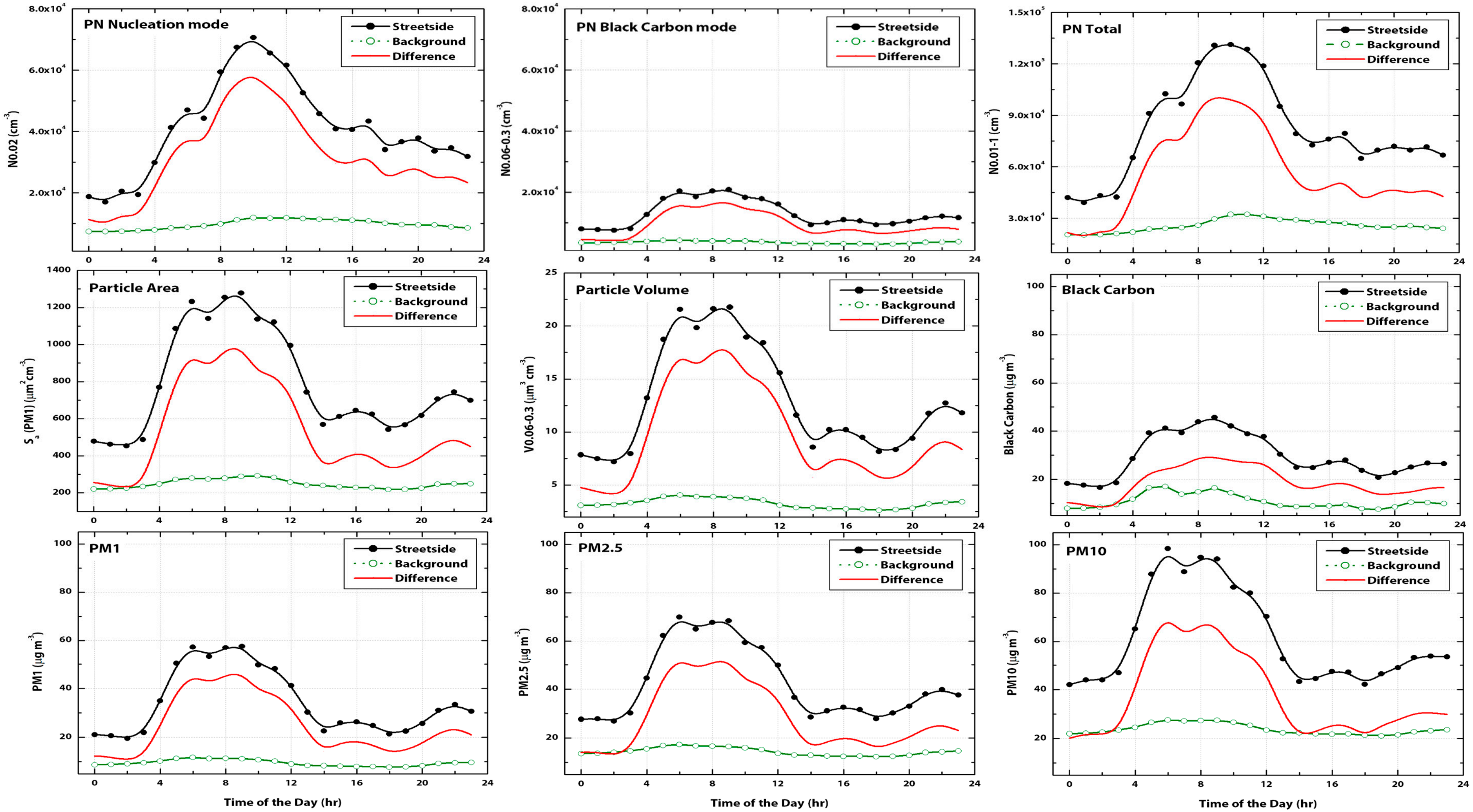

Figure S2. Curbside and derived Background concentration.

Presented here (Fig. S2) are the results of the derived background concentration from the suggested method in Kecorius et al. [1], which is based on the principle of pollution contribution described in Fuzzi et al. [2]. The idea is at the street canyon, the concentration of pollutants is the superposition of the urban background that is the result of regional pollution and the contributions from the city itself plus the direct tailpipe emission from vehicles in the street, which is observed as high peaks from MPSS measurements. Following this logic, a rolling minimum to the sudden high values from MPSS gives the urban background pollution level.

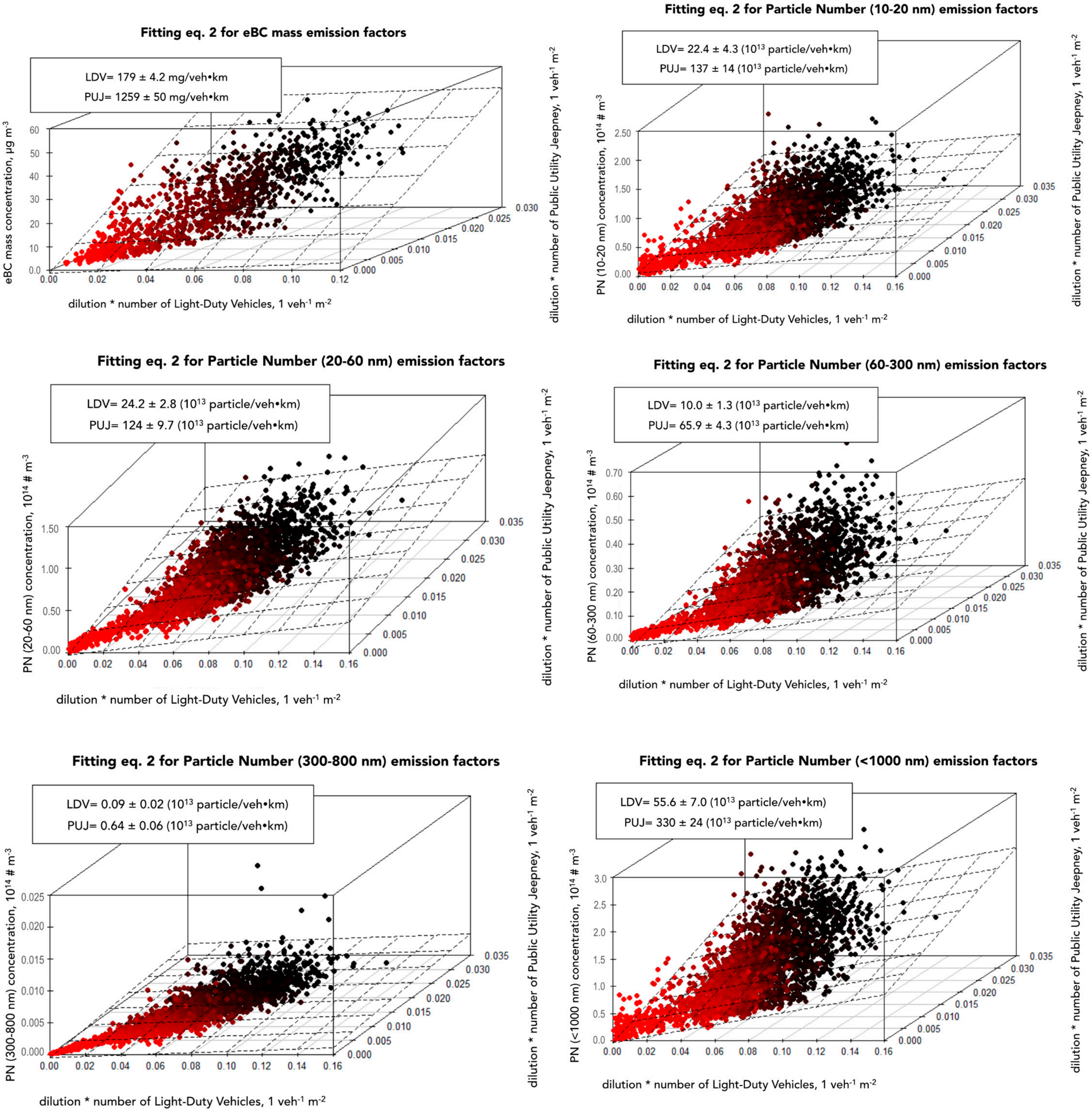

Figure S3. The results of bivariate linear regression from solving Eq. 2. The output indicates that the fitted value is given by $\hat{y} = \alpha + \beta x_1 + \gamma x_2$, where β and γ are the emission factors for LDV and PUJs, respectively. Plane represents the best fit with R^2 values of 0.6, 0.2, 0.3, 0.3, 0.2, and 0.2 for BC, $PN_{10\text{–}20\,nm}$, $PN_{20\text{–}60\,nm}$, $PN_{60\text{–}300\,nm}$, $PN_{300\text{–}800\,nm}$, and $PN_{<1000\,nm}$, respectively.

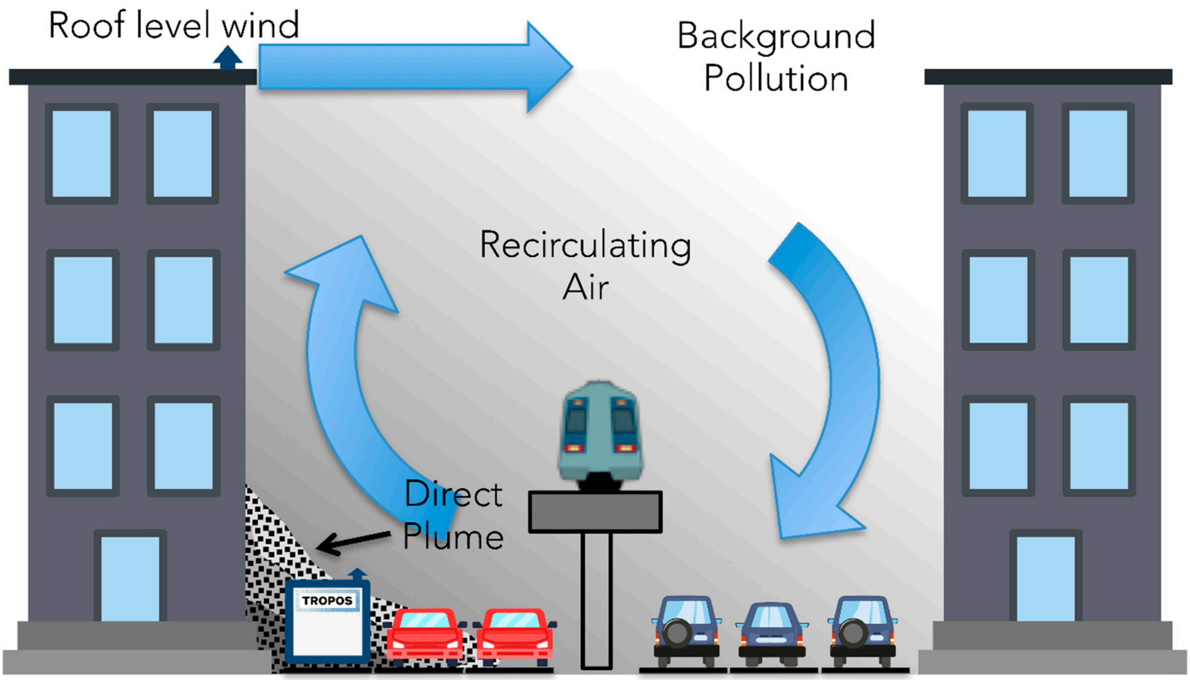

Figure S4. Brief explanation of Operational Street Pollution Model (OSPM).

On streets, e.g. both sides are occupied with buildings, a mixing and dilution of vehicular pollution appears due to wind and traffic generated turbulence [3]. The Operational Street Pollution Model (OSPM) predicts the concentration of traffic exhaust by combining the plume and box models. The plume model predicts the dilution by direct contribution of emissions from the tailpipe to the particle inlet. The box model predicts the concentrations that are not directly coming from the vehicles but as a result of recirculation of the polluted air. The OSPM makes parameterizations on the flow and dispersion conditions within a street canyon. These parameterizations were derived from extensive analysis of experimental and model tests [4]. Schematic illustration of the basic model principles used in OSPM is shown in Fig. S4.

Table S3. Summary of mass emission factor compared to other literature. Emphasis is directed towards the urban road EF. The *jeepney* vehicle characterized in our study were compared to heavy-duty vehicles (HDV) of other studies. Background colour represents EF where night time values were excluded (dark gray) or included (light gray) in the calculation. YoM—year of measurements. MP—measured parameter.

Study	YoM	Location	Site	Emission Factor (mg/veh·km)			
				MP	Fleet	LDV	HDV
This study	2015	Manila, Philippines	Urban	BC	336 ± 4.2	179 ± 4.2	1259 ± 50
	Including night time values			BC	349 ± 4.1	35 ± 28	1594 ±105
Imhof et al. [5]	2002	Zurich, Switzerland	Urban	BC	35 ± 3.0	10 ± 1.0	427 ± 33
Westerdahl et al. [6]	2007	Beijing, China	Urban	BC	-	26.6	1224
Sánchez-Ccoyllo et al. [7]	2004	São Paolo, Brazil	Tunnel	BC	-	16 ± 5	462 ± 112
Kecorius et al. [1]	2015	Manila, Philippines	Urban	BC	313	27	1618
Krecl et al. [8]	2016	Londrina, Brazil	Urban	BC	-	26 ± 12	691 ± 67
Miranda et al. [9]	2015	São Paolo, Brazil	Highway	BC	-	41 ± 63	170 ± 259
This Study	2015	Manila, Philippines	Urban	PM_1	465 ± 5.7	264 ± 37	1969 ± 120
Including night time values				PM_1	480 ± 8.3	§	3789 ± 206
Imhof et al. [10]	2001	Platsburch, Austria	Tunnel	PM_1	104 ± 4.0	36 ± 6.0	306 ± 24
		Kingsway, UK	Tunnel	PM_1	41 ± 4.0	21 ± 3.0	310 ± 39
This Study	2015	Manila, Philippines	Urban	$PM_{2.5}$	529 ± 6.3	283 ± 41	2240 ± 140
Including night time values				$PM_{2.5}$	539 ± 9.5	§	4362 ± 235
Ferm et al. [11]	2012	Gothenburg, Sweden	Urban	$PM_{2.5}$	21 ± 9.0	-	-
Cheng et al. [12]	2003	Hong Kong, HK	Tunnel	$PM_{2.5}$	257 ± 31	-	-
Imhof et al. [10]	2001	Kingsway, UK	Tunnel	$PM_{2.5}$	49 ± 5.0	19 ± 6.0	381 ± 63
Wang et al. [13]	2008	Copenhagen, Denmark	Highway	$PM_{2.5}$	29 ± 1.0	11 ± 2.0	233 ± 18
Abu Allaban et al. [14]	2000	J.Motley, North Carolina	Freeway	$PM_{2.5}$	-	50 ± 17	800 ± 300
This Study	2015	Manila, Philippines	Urban	PM_{10}	708 ± 8.8	355 ± 57	2958 ± 190
Including night time values				PM_{10}	713 ± 13	§	5834 ± 328
Ferm et al. [11]	2012	Gothenburg, Sweden	Urban	PM_{10}	60 ± 9.0	-	-
Vergel and Tiglao, [15]	---	Quezon City, Philippines	Dynamo-meter	TSP	-	780	900
Bukowiecki et al. [16]	2007	Zurich, Switzerland	Urban	PM_{10}	71	24 ± 7.5	498 ± 86
Wang et al. [13]	2008	Copenhagen, Denmark	Highway	PM_{10}	131 ± 4.0	44 ± 7.0	1087 ± 68
Abu Allaban et al. [14]	2000	J.Motley, North Carolina	Freeway	PM_{10}	-	260 ± 90.0	3700 ± 1300
European Emission Standards (Euro 5, Euro 6)				PM	5	5	10

Table S4. Summary of number emission factor compared to other literature. The *jeepney* vehicle were compared to HDV. Background colour represents EF where night time values were excluded (dark gray) or included (light gray) in the calculation. YoM—year of measurements.

Study	YoM	Location	Site	Emission Factor (10^{13} particles/veh·km)			
				Size (nm)	Fleet	LDV	HDV
This study	2015	Manila, Philippines	Urban	N_{10-20}	53.5 ± 0.64	22.4 ± 4.3	137 ± 14
				N_{20-60}	41.0 ± 0.43	24.2 ± 2.8	124 ± 9.7
				N_{60-300}	17.6 ± 0.20	10.0 ± 1.3	65.9 ± 4.3
				$N_{300-800}$	0.15 ± 0.003	0.09 ± 0.02	0.64 ± 0.06
				N_{tot}	106 ± 1.1	55.6 ± 7.0	330 ± 24
				PA^a	9800 ± 106	5320 ± 680	42100 ± 2300
				PV^b	0.25 ± 0.003	0.13 ± 0.019	1.06 ± 0.064
Including night time values				N_{10-20}	59.3 ± 0.88	21 ± 6.4	205 ± 25
				N_{20-60}	36.7 ± 0.53	5.76 ± 3.7	166 ± 14
				N_{60-300}	18 ± 0.27	§	121 ± 6.9
				$N_{300-800}$	0.16 ± 0.003	§	1.29 ± 0.087
				N_{tot}	107 ± 1.5	12.6 ± 10	501 ± 39
Ketzel et al.[18]	2001	Copenhagen, Denmark	Urban	N_{10-700}	28	-	-
Imhof et al.[5]	2002	Zurich, Switzerland	Urban	N_{18-50}	6.4 ± 0.4	2.6 ± 0.2	73 ± 3.0
				N_{18-100}	9.0 ± 0.5	3.8 ± 0.2	105 ± 3
				N_{18-300}	11.2 ± 0.7	4.6 ± 0.20	132 ± 3.0
				$N_{>7}$	38.6 ± 1.8	8.0 ± 0.9	550 ± 10
				PV_{18-300}^b	0.068 ± 0.006	0.027 ± 0.002	0.934 ± 0.03
Imhof et al.[10]	2001	Plabutsch, Austria	Tunnel	N_{18-700}	15 ± 0.8	5.9 ± 0.9	39.4 ± 3.1
				PV_{18-700}^b	0.21 ± 0.008	0.07 ± 0.013	0.61 ± 0.05
		Kingsway, UK	Tunnel	N_{18-700}	12.6 ± 1.0	5.9 ± 1.1	68.4 ± 12
				PV_{18-700}^b	0.04 ± 0.04	0.02 ± 0.003	0.20 ± 0.038
Rose et al.[18]	2003	Leipzig, Germany	Urban	Soot	15 ± 4.0	5.8 ± 2.0	250 ± 90
Jones and Harrison, [19]	2003	London, UK	Urban	N_{11-437}	-	5.8	63.6
Birmili et al.[20]	2005	Berlin, Germany	Urban	N_{10-500}	21 ± 2	2.4 ± 1.5	296 ± 35
				Soot	7.8 ± 1	-	-
Klose et al.[21]	2006	Leipzig, Germany	Urban	N_{4-800}	-	54 ± 2	4300 ± 1700
Wang et al.[13]	2008	Copenhagen, Denmark	Urban	N_{10-700}	18.7 ± 3.0	10.0	221
			Urban	N_{10-50}	10.1 ± 0.24	3.9 ± 0.48	155 ± 10
			Urban	N_{50-100}	4.70 ± 0.14	3.4 ± 0.31	33.5 ± 6.4
			Urban	$N_{100-700}$	2.02 ± 0.11	0.86 ± 0.24	29.0 ± 0.50
			Highway	N_{10-700}	21.5 ± 0.53	8.1 ± 0.69	175 ± 6.8
Kecorius et al.[1]	2015	Manila, Philippines	Urban	RP^c	32.9	9.79	115
Krecl et al.[8]	2016	Londrina, Brazil	Urban	$N_{<1000}$	-	92.5 ± 11	373 ± 58
European Emission Standards (Euro 5, Euro 6)				PN	0.06	0.06	0.08

[a]PA EF unit is cm^2/(veh·km); [b]PV EF unit is cm^3/(veh·km); [c]RP, Refractory Particles (a proxy for soot); § - not retrieved.

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