atmosphere

MDPI

SUPPLEMENTARY MATERIAL

Commuter exposure to black carbon, fine particulate matter and particle number concentration in ferry and the pier in Istanbul

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Supplementary S1

Table S1. The ferry characteristics.

Transport Mode	Type	Width (m)	Length (m)	Speed (knot)	Passenger Capacity	Car Capacity
Fast ferry	Catamaran	10	35	32	400	-
Car ferry	Double ended	21	82.27	22	600	108

Table S2. Ferry activity and external emission sources at the piers.

Piers	Departure/day (summer)	Departure/day (winter)	Local Emission Sources	External Emission Sources
Bakırköy	6	6	Fast ferry	Poor road traffic, yacht marina activity near the pier
Kadıköy	149	147	Slow ferry (95%) Fast ferry (5%)	Very high road traffic, intense residential&commercial area,
Bostancı	76	53	Slow ferry (13%) Fast ferry (87%)	High road traffic, intense residential area, slow ferry activities near the pier.
Yenikapı	47	22	Fast ferry,car ferry	Very high road traffic
Yalova	28	23	Car ferry	High road traffic, shipping port activities (Yalova-Topçular port) about 5 km away from the pier.

Table S3. The mean concentrations in fast ferry and car ferry in the monthly basis.

Months	Fast Ferry			Car Ferry		
	PNC (pt cm^{-3})	BC ($\mu g\ m^{-3}$)	$PM_{2.5}$ ($\mu g\ m^{-3}$)	PNC (pt cm^{-3})	BC ($\mu g\ m^{-3}$)	$PM_{2.5}$ ($\mu g\ m^{-3}$)
January	-	-	-	16866	0.9	16.5
February	-	-	-	16598	1.2	19.7
March	51109	12.3	-	-	-	-
April	23680	10.9	16.0	-	-	-
May	18535	4.8	19.8	-	-	-
June	31904	9.7	12.1	27376	0.4	3.5
July	21332	7.7	12.4	24088	1.3	21.4
August	16839	13.3	24.0	12122	1.6	5.8
September	16401	17.0	22.9	28468	2.3	19.9
October	25158	4.4	19.0	18268	0.7	13.2
November	25550	1.4	26.8	23547	-	16.3
December	28639	1.5	26.0	20190	0.7	16.4

Table S4. The median concentrations in fast ferry and car ferry in the monthly basis.

Months	Fast Ferry			Car Ferry		
	PNC (pt cm^{-3})	BC ($\mu g\ m^{-3}$)	$PM_{2.5}$ ($\mu g\ m^{-3}$)	PNC (pt cm^{-3})	BC ($\mu g\ m^{-3}$)	$PM_{2.5}$ ($\mu g\ m^{-3}$)
January	-	-	-	16993	2,3	16,1
February	-	-	-	16749	1,1	19,3
March	46935	11,3	-	-	-	-
April	17531	9,0	15,0	-	-	-
May	15625	4,2	19,8	-	-	-
June	29194	8,3	9,7	23743	0,4	2,8
July	17963	6,3	10,8	23860	1,3	21,4
August	13797	11,1	22,8	9298	1,3	5,6
September	14142	15,4	22,6	28468	2,2	18,9
October	15298	2,2	16,7	20002	0,7	13,3
November	14875	2,1	25,2	23245	-	12,6
December	21400	2,6	24,9	19749	0,3	16,1

Table S5. The mean concentrations at the pier in the monthly basis.

Months	Bakırköy			Bostancı			Yenikapı			Yalova		
	UFP (pt cm^{-3})	BC (µg m^{-3})	$PM_{2.5}$ (µg m^{-3})	UFP (pt cm^{-3})	BC (µg m^{-3})	$PM_{2.5}$ (µg m^{-3})	UFP (pt cm^{-3})	BC (µg m^{-3})	$PM_{2.5}$ (µg m^{-3})	UFP (pt cm^{-3})	BC (µg m^{-3})	$PM_{2.5}$ (µg m^{-3})
January	-	-	-	-	-	-	39306	9.6	36.3	6375	2.8	25.4
February	-	-	-	-	-	-	34760	13.8	31.9	60349	32.9	26.3
March	49405	16.4	-	18731	36.4	-	-	-	-	-	-	-
April	30271	9.0	31.9	15173	3.2	23.0	-	-	-	-	-	-
May	54799	5.6	27.3	23006	16.7	31.0	-	-	-	-	-	-
June	33001	6.7	14.9	31459	35.9	22.1	11363	1.1	7.2	101886	8.7	10.5
July	19695	8.2	13.3	16076	29.1	19.7	14548	2.9	34.8	54891	18.5	29.2
August	13651	7.0	24.1	20168	22.1	24.3	25354	2.8	12.8	33667	9.4	11.2
September	16426	2.5	218	10711	5.8	23.8	10998	3.6	22.7	7786	2.5	31.0
October	51836	2.6	26.8	14736	2.8	71.9	13429	1.6	17.5	34722	7.6	19.9
November	45512	2.1	31.8	53199	21.7	32.7	36444	8.5	34.4	36361	16.4	34.2
December	34506	2.7	34.8	17531	2.9	36.6	28774	4.3	40.9	-	-	-

Table S6. The median concentrations at the pier in the monthly basis.

Months	Bakırköy			Bostancı			Yenikapı			Yalova		
	UFP (pt cm^{-3})	BC (µg m^{-3})	$PM_{2.5}$ (µg m^{-3})	UFP (pt cm^{-3})	BC (µg m^{-3})	$PM_{2.5}$ (µg m^{-3})	UFP (pt cm^{-3})	BC (µg m^{-3})	$PM_{2.5}$ (µg m^{-3})	UFP (pt cm^{-3})	BC (µg m^{-3})	$PM_{2.5}$ (µg m^{-3})
January	-	-	-	-	-	-	36775	9.1	35.0	6115	2.3	21.0
February	-	-	-	-	-	-	31651	13.5	29.9	52090	26.8	19.1
March	46644	15.9	-	17110	37.3	-	-	-	-	-	-	-
April	28798	8.4	29.2	14632	3.3	22.6	-	-	-	-	-	-
May	53589	4.8	27.3	26106	7.9	31.0	-	-	-	-	-	-
June	29805	3.5	14.1	24888	19.1	19.7	11063	0.5	6.3	99937	6.4	8.4
July	18394	7.3	12.2	14714	26.0	17.5	11092	1.8	33.6	53281	16.9	27.3
August	10733	6.6	23.5	15041	9.5	22.2	22684	0.8	10.2	35244	0.5	8.8
September	14898	1.7	21.0	10179	5.6	22.9	10904	3.2	18.2	7889	2.0	30.8
October	52909	3.1	25.6	12393	1.9	69.9	13306	1.0	16.8	29122	5.0	17.5
November	41054	1.9	29.5	53199	17.3	31.4	35773	7.7	34.3	31953	13.1	25.9
December	32156	2.5	33.1	16389	2.3	33.9	27842	4.4	39.2	-	-	-


Bakırköy Pier
Yacht Marina
Google Earth
600 m

(a)

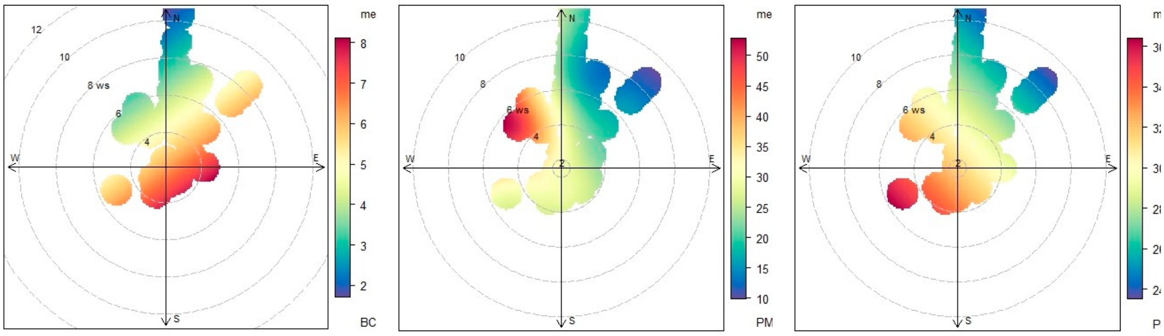

Bostancı Pier
Google Earth

(b)

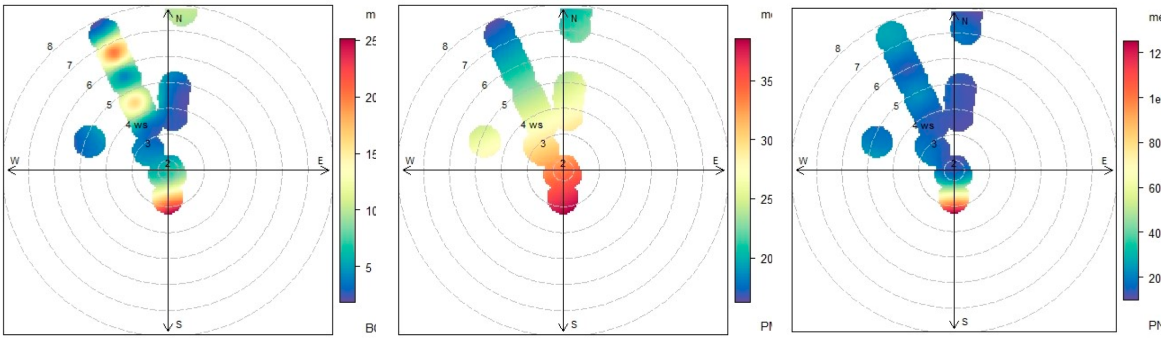
(c)

(d)

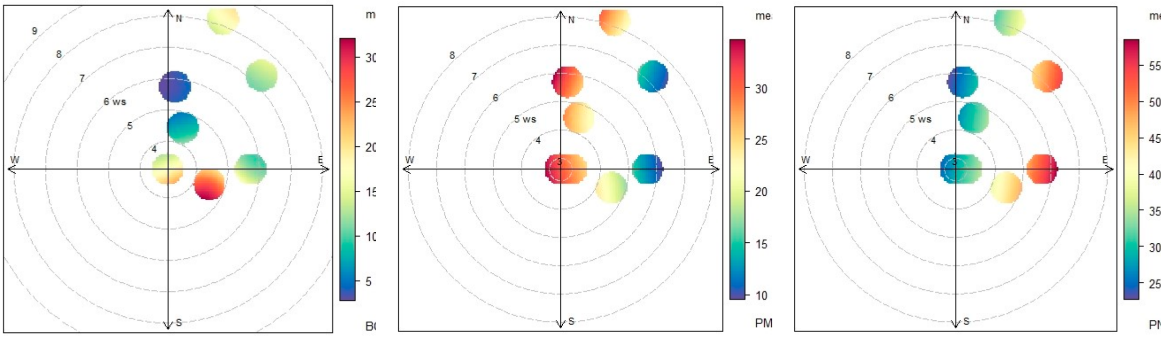
Figure S1. The location of the piers (**a**) Bakırköy pier and yacht marina, (**b**) Bostancı pier (**c**) Yenikapı pier (**d**) Yalova pier and Yalova-Topçular Port.



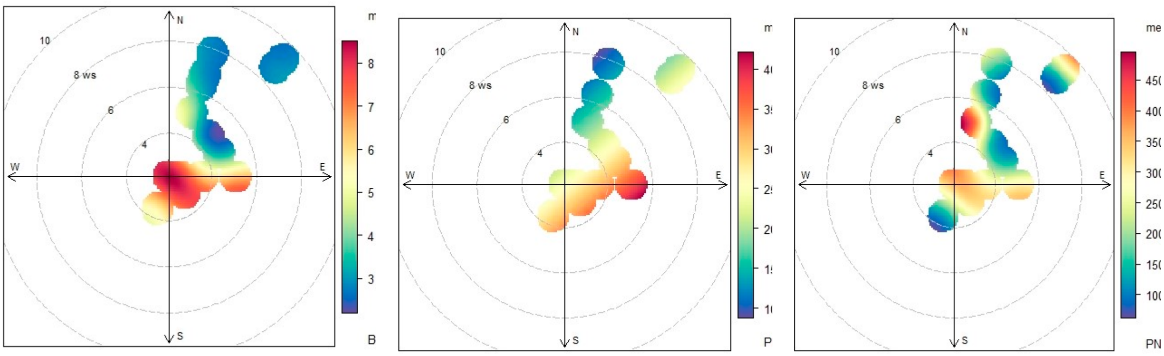
(a) Bakırköy Pier



(b) Bostancı pier



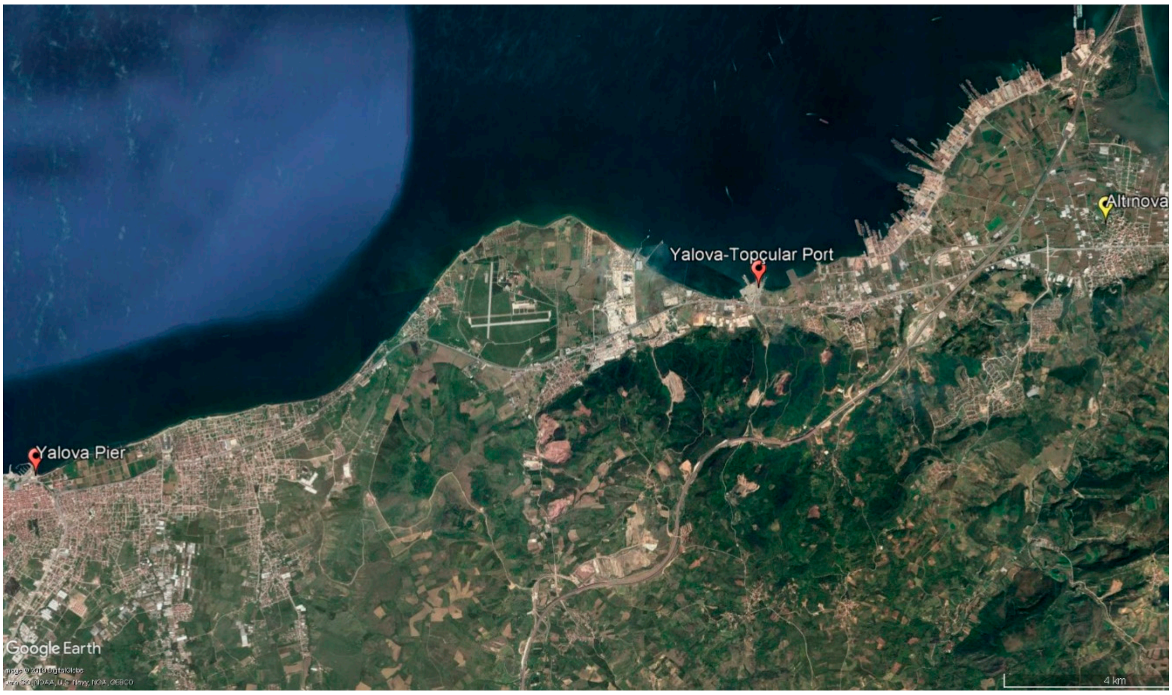
(c) Yalova Pier



(d) Yenikapı pier

Figure S2. Polar plots of analysed air pollutants. BC, $PM_{2.5}$ and PNC data were horly- averaged to be matched with wind data.

(a)



(b)

Figure S3. Air Quality monitoring stations (yellow mark) and the piers (red mark) (**a**) Bakırköy-Bostancı-Yenikapı piers (**b**) Yalova pier.

Table S7. Exposure concentrations of PNC, BC and PM2.5 (median ± std) for ferry and pier.

Commute Mode	Exposure		
	UFP (particles)	BC (μg)	$PM_{2.5}$ (μg)
Fast ferry	$78.5E^{+8} \pm 70.7E^{+8}$	2.4 ± 4.1	8.5 ± 4.8
Bakırköy pier	$14.3E^{+8} \pm 14.8E^{+8}$	0.2 ± 0.5	1.4 ± 1.1
Bostancı pier	$8.9E^{+8} \pm 9.9E^{+8}$	0.3 ± 1.2	1.5 ± 2.0
Car ferry	$195.2E^{+8} \pm 87.1E^{+8}$	1.2 ± 2.6	14.7 ± 8.2
Yenikapı pier	$17.7E^{+8} \pm 12.8E^{+8}$	0.3 ± 1.3	1.5 ± 1.1
Yalova pier	$20.7E^{+8} \pm 17.8E^{+8}$	0.4 ± 0.7	1.3 ± 1.4

Table S8. Exposure per/kilometer for PNC, BC and $PM_{2.5}$. and comparison to the previous study in Istanbul.

Commute Mode	Exposure		
	PNC (particles/km)	BC (μg/km)	$PM_{2.5}$ (μg/km)
Fast ferry	$3.73E^{+8} \pm 2.0E^{+8}$	0.11 ± 0.07	0.29 ± 0.14
Car ferry	$3.88E^{+8} \pm 1.3E^{+8}$	0.02 ± 0.01	0.27 ± 0.12
Bus	$7.0E^{+8} \pm 3.6E^{+8}$	0.22 ± 0.17	0.74 ± 0.40
Light-rail	$2.4E^{+8} \pm 1.4E^{+8}$	0.07 ± 0.03	0.33 ± 0.21
Car Windows closed	$1.0E+^{8} \pm 0.9E+$	0.03 ± 0.03	0.10 ± 0.11

Table S9. Monthly average of meteorological parameters.

	Temp. (°C)	Humidity (%)	Atmospheric Pressure (hPa)	Wind Speed (m/s)
January	4.0	76.1	1017.4	5.7
February	7.0	73.9	1019.6	4.3
March	10.0	70.9	1012.6	4.3
April	19.5	61.1	1013.3	3.6
May	17.7	68.9	1010.7	4.2
June	24.1	59.0	1009.0	4.5
July	26.2	56.0	1009.1	5.1
August	26.5	64.0	1009.8	5.7
September	22.6	59.9	1012.6	4.6
October	17.0	66.4	1016.1	4.4
November	12.8	63.1	1016.9	4.7
December	5.5	71.2	1021.6	5.6

Supplementary S2:

The commuter exposure per mile and per kilometer were estimated according to the equation-S1 as given below [1]. Only the in-vessel/vehicle personal exposures during trips were calculated using this equation. The per-minute ventilation rates for fast ferry and car ferry were assumed to be 12.7 L min^{-1}.

Equation-S1:

$$\text{Commute exposure } (\mu g/km) = [\text{Concentration } (\mu g\ m^{-3}) \text{ x Time (min)/Distance (km)}] \times \text{Inhalation Rate } (m^3\ min^{-1})$$

Supplementary S3:

Calibration for pDR 1200

A comparison between Thermo pDR 1200 (light-scattering method) and Thermo Partisol FRM (gravimetric method) was conducted. Thermo pDR 1200 and Thermo partisol FRM samples were collocated and measurements were taken simultaneously for 10 consecutive days. The gravimetric analysis of $PM_{2.5}$ concentrations was conducted using an electronic balance with a sensitivity of 0.01 mg. Figure S1 shows the correlation (R^2 = 0.79) between the two methods. $PM_{2.5}$ concentrations measured in this study were corrected using this correlation.

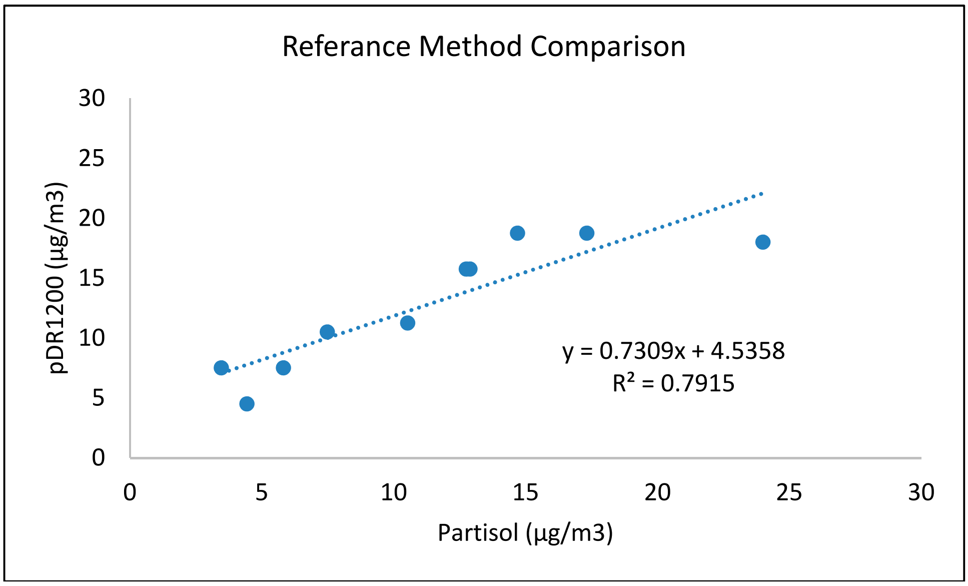


Figure S1. Comparison of Thermo pDR 1200 and Thermo Partisol FRM sampler $PM_{2.5}$ measurements.

PNC

PNC measurements >100000 particles cm^{-3} were corrected to prevent the underestimation of particle counts at high concentrations measured by TSI model 3007 CPC [2]. The following equation was used for the correction:

$$y = 38456e^{0.00001x} \text{ for } x > 100{,}000\ cm^{-3},$$

where x = the CPC reading for PNC concentration and y = the adjusted PNC value. The corrected data was ~0.1% of total PNC data.

BC

The micro-aethalometer (Model AE51) was used to collect BC data. The filter strips in the AE51 were changed when attenuation value was in the range of 75–80. BC data has noise (peak and negative values) because of instrument maintenance; measurement sensitivity, such as vibration; humidity; flow rate; and operating conditions. Some data will be higher or lower than the actual value. These deviations and negative values are needed for post-processing or smoothing. There are various smoothing algorithms found on the manufacturer's website (aethlabs.com). The Optimized Noise-reduction Averaging (ONA) algorithm, which was developed by Hagler et al. (2011), was first applied for smoothing our BC data. The ONA algorithm decreases the occurrence of negative values to nearly zero while protecting the trends in the time series.

Next, a correction was applied for filter loading. Specifically, with the aethalometer (filter-based light transmission method), the BC attenuation coefficient decreases with increased BC mass loading. The adjustment for filter loading was applied using the following equations [3,4]:

$$ATN = 100 \ln (I_o/I),$$

where ATN is the attenuation factor, intensities I_o and I correspond to the initial and subsequent filter conditions (Ref/Sens);

$$Tr = \exp(ATN/100),$$

where Tr is the measured filter transmission; and

$$BC_{abs} = BC_i/(0.88 \times Tr + 0.12),$$

where BC_{abs} is the corrected BC and BC_i is the initial BC value.

References

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