Size-segregated characteristics of OC, EC and organic matters in PM emitted from different types of ships in China

Fan Zhang^{1,2}, Hai Guo^{1*}, Yingjun Chen^{2,3,4*}, Volker Matthias⁵, Yan Zhang², Xin Yang^{2,4}, Jianmin Chen²

5 ¹Air Quality Studies, Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hong Kong, P.R. China

²Shanghai Key Laboratory of Atmospheric Particle Pollution and Prevention (LAP3), Department of Environmental Science and Engineering, Fudan University, Shanghai 200092, P.R. China

10 ³Key Laboratory of Pollution Control and Resource Reuse, College of Environmental Science and Engineering, Tongji University, Shanghai 200092, P.R. China

⁴Shanghai Institute of Pollution Control and Ecological Security, Shanghai 200092, P.R. China

⁵Helmholtz-Zentrum Geesthacht, Institute of Coastal Research, Max-Planck-Straße 1,
15 21502 Geesthacht, Germany

Correspondence: Hai Guo (hai.guo@polyu.edu.hk)

Yingjun Chen (yjchenfd@fudan.edu.cn)

Table S1 Technical parameters of test vessels

Vessel ID	Engine power (kW)	Vessel type	Length × width (m)	Material	Vessel age (year)	Rated speed (rpm)	Fuel type	Classified Type
GB1	91	Gillnet	20×4.3	Wooden	10	1500	Diesel	LPDF
GB2	178	Gillnet	27×5.6	Wooden	7	1500	Diesel	
AB1	129	Angling boat	21×4.3	Wooden	6	1500	Diesel	
AB2	176	Angling boat	22.7×4.8	Wooden	5	1800	Diesel	
TB1	88	Trawler	13×3.5	Wooden	8	1500	Diesel	
TB2	132	Trawler	13×3.5	Wooden	5	1500	Diesel	
TB5	265	Trawler	29×5.4	Metal	10	1800	Diesel	
TB6	265	Trawler	29×5.4	Metal	10	1800	Diesel	
HH	350×2	Engineering vessel	44×13	Metal	4	1200	Diesel	HPDV
DFH	1600×2	Research vessel	96×15	Metal	18	900	Diesel	
XYH	600	Research vessel	55×9	Metal	5	1000	Diesel	
YK	4440	Training vessel	116×18	Metal	11	173	HFO	HFOV

Table S2 Results of the fuel quality analysis

Vessel ID	Carbon (C) %	Hydrogen (H) %	Oxygen (O) %	Nitrogen (N) %	Sulfur (S) %	Gross calorific value MJ/kg	Net calorific value MJ/kg	Kinematical viscosity (40°C) mm ² /s
GB1	85.96	12.76	<0.3	0.49	0.022	45.83	42.79	4.517
GB2	86.09	12.67	0.6	0.61	0.169	45.32	42.41	2.639
AB1	86.35	12.73	<0.3	0.49	0.111	45.79	42.75	2.430
AB2	85.72	12.73	<0.3	0.49	0.046	45.42	42.48	2.782
TB1/TB2	86.21	11.50	2.03	0.05	0.066	45.01	42.42	4.125
TB5/TB6	85.92	12.49	<0.3	0.41	0.284	45.26	42.37	2.646
HH	86.66	13.32	< 0.4	< 0.2	0.080	45.44	42.51	N.A.
DFH	86.40	13.22	< 0.4	< 0.2	0.046	45.40	42.48	N.A.
XYH	86.49	13.44	< 0.4	< 0.2	0.130	45.50	42.55	N.A.
YK	84.12	10.38	4.26	0.79	0.448	43.50	41.10	N.A.

N.A., Not Analyzed.

Table S3 Size-resolved particle samples collected in this study

Vessel ID	Operating mode	Quantity	Vessel ID	Operating mode	Quantity
YK	Manoeuvring	2	TB5	Trawling	1
	Cruise	3	TB6	Trawling	1
GB1	Placing/drawing in net	1		High speed	1
	cruise	1	HH	Low speed	1
GB2	Idling	1		Cruise	2
	High speed	1	XYH	Idling	1
AB1	High speed	1		Cruise	1
AB2	Idling/angling	2	DFH	Idling	1
TB1	Idling	1		Acceleration	2
	Medium speed	1		Cruise	1
TB2	Idling	1			
	Medium speed	1			

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Table S4 Particle size fractions of 8 Stage Andersen Cascade Impactor

Stage	Particle size range (μm)	Sampling spot number
0	>9.0	96
1	5.8-9.0	96
2	4.7-5.8	400
3	3.3-4.7	400
4	2.1-3.3	400
5	1.1-2.1	400
6	0.65-1.1	400
7	0.43-0.65	201
8	<0.43	--

--, the sampling area in this stage is a circle with diameter of 7.94 cm.

Table S5 16 priority PAHs and their abbreviations

	Abbreviation	Number of rings
Napthalene	Nap	2
Acenaphthylene	Acy	2
Acenaphthene	Ace	2
Fluorene	Flu	3
Phenanthrene	Phe	3
Anthracene	Ant	3
Fluoranthene	Flua	4
Pyrene	Pyr	4
Benzo[a]anthracene	BaA	4
Chrysene	Chr	4
Benzo[b]fluoranthene	BbF	5
Benzo[k]fluoranthene	BkF	5
Benzo[a]pyrene	BaP	5
Indeno[1,2,3-cd]pyrene	IcdP	6
Dibenzo[a,h]anthracene	DahA	5
Benzo[ghi]perylene	BghiP	6

Table S6 average recoveries of the deuterium surrogates

D-PAHs	Average recovery $\pm$ SD	D-n-alkanes	Average recovery $\pm$ SD
D8- Naphthalene	84.3 $\pm$ 10.5	D-C16	95.0 $\pm$ 7.48
D10- acenaphthene	101 $\pm$ 11.8	D-C20	96.1 $\pm$ 14.2
D10- phenanthrene	99.5 $\pm$ 8.24	D-C24	97.2 $\pm$ 15.5
D12- chrysene	95.1 $\pm$ 14.2	D-C30	92.0 $\pm$ 14.9
D12-perylene	84.8 $\pm$ 16.4		

Table S7 OC and EC distributions in different particle size bins (%)

	Particle size (μm)	HFOV	HPDV	LPDF
OC	<0.43	74.7 $\pm$ 4.84	22.9 $\pm$ 11.2	42.6 $\pm$ 14.6
	0.43-0.65	7.10 $\pm$ 1.80	15.9 $\pm$ 3.52	21.5 $\pm$ 9.64
	0.65-1.1	4.61 $\pm$ 1.55	14.0 $\pm$ 2.93	9.62 $\pm$ 2.50
	1.1-2.1	3.48 $\pm$ 1.56	11.0 $\pm$ 2.23	7.12 $\pm$ 3.52
	2.1-3.3	3.18 $\pm$ 1.91	8.73 $\pm$ 2.27	4.96 $\pm$ 3.19
	3.3-4.7	2.24 $\pm$ 0.67	8.39 $\pm$ 2.67	4.89 $\pm$ 3.50
	4.7-5.8	2.15 $\pm$ 0.87	9.42 $\pm$ 5.83	4.85 $\pm$ 3.78
	5.8-9.0	1.34 $\pm$ 0.63	3.99 $\pm$ 0.94	2.08 $\pm$ 1.50
	>9.0	1.18 $\pm$ 0.55	5.64 $\pm$ 2.32	2.33 $\pm$ 1.87
EC	<0.43	65.9 $\pm$ 9.87	27.3 $\pm$ 8.86	31.7 $\pm$ 13.3
	0.43-0.65	14.7 $\pm$ 6.65	22.0 $\pm$ 6.50	32.2 $\pm$ 11.1
	0.65-1.1	6.93 $\pm$ 1.76	18.8 $\pm$ 5.37	14.2 $\pm$ 6.11
	1.1-2.1	3.71 $\pm$ 1.68	16.3 $\pm$ 5.59	9.10 $\pm$ 4.58
	2.1-3.3	1.99 $\pm$ 2.42	4.92 $\pm$ 2.99	4.15 $\pm$ 2.29
	3.3-4.7	2.14 $\pm$ 2.08	3.45 $\pm$ 2.08	3.18 $\pm$ 2.90
	4.7-5.8	2.09 $\pm$ 1.89	2.03 $\pm$ 1.98	3.30 $\pm$ 3.22
	5.8-9.0	1.86 $\pm$ 2.47	1.02 $\pm$ 0.93	1.16 $\pm$ 1.21
	>9.0	0.71 $\pm$ 0.67	4.22 $\pm$ 6.24	1.07 $\pm$ 0.88

Table S8 The distribution of total PAHs and total n-alkanes in different particle size

bins (%)				
	Particle size (μm)	HFOV	HPDV	LPDF
PAHs	<0.43	78.6 $\pm$ 2.78	37.6 $\pm$ 12.8	59.5 $\pm$ 13.1
	0.43-0.65	4.90 $\pm$ 1.54	14.7 $\pm$ 8.72	16.4 $\pm$ 6.56
	0.65-1.1	4.51 $\pm$ 0.81	14.0 $\pm$ 6.65	10.1 $\pm$ 4.51
	1.1-2.1	2.32 $\pm$ 1.48	10.9 $\pm$ 7.14	5.56 $\pm$ 3.49
	2.1-3.3	3.22 $\pm$ 1.43	7.52 $\pm$ 3.49	2.91 $\pm$ 2.45
	3.3-4.7	2.27 $\pm$ 1.88	5.22 $\pm$ 2.26	2.10 $\pm$ 1.76
	4.7-5.8	3.12 $\pm$ 0.75	5.58 $\pm$ 2.76	1.58 $\pm$ 2.05
	5.8-9.0	0.49 $\pm$ 0.28	1.97 $\pm$ 1.55	0.72 $\pm$ 0.90
	>9.0	0.55 $\pm$ 0.25	2.47 $\pm$ 3.94	1.11 $\pm$ 2.10
N-alkanes	<0.43	90.2 $\pm$ 2.99	54.4 $\pm$ 23.5	51.0 $\pm$ 17.2
	0.43-0.65	2.05 $\pm$ 0.77	11.9 $\pm$ 6.47	16.1 $\pm$ 7.05
	0.65-1.1	2.35 $\pm$ 0.79	12.7 $\pm$ 8.51	16.5 $\pm$ 11.9
	1.1-2.1	1.39 $\pm$ 0.83	7.20 $\pm$ 6.47	7.07 $\pm$ 4.71
	2.1-3.3	1.28 $\pm$ 0.43	5.65 $\pm$ 8.00	3.25 $\pm$ 2.60
	3.3-4.7	0.80 $\pm$ 0.74	2.96 $\pm$ 3.42	2.80 $\pm$ 3.30
	4.7-5.8	1.25 $\pm$ 0.44	3.27 $\pm$ 4.07	2.07 $\pm$ 2.26
	5.8-9.0	0.32 $\pm$ 0.07	0.87 $\pm$ 1.38	0.54 $\pm$ 0.49
	>9.0	0.40 $\pm$ 0.09	1.02 $\pm$ 1.57	0.74 $\pm$ 1.00

Figure S1 Size-segregated particle mass distribution of auxiliary engines

Figure S2 Ratio of high molecular weight PAH to low molecular weight PAH