Supporting information for

Impact of Seasonal Variability and Atmospheric Compositions on the Bacterial and Fungal Communities and Functions of $PM_{2.5}$ in Seoul, Republic of Korea

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Table S1. Information on the environmental factors considered for the seasonal samples (Kang, 2021)

Table S2. Seasonal OTUs and α-diversity indices of the bacterial and fungal communities in the PM2.5 samples.

Table S3. Trophic mode and guild of the dominant fungi at the genus level parsed using FUNGuild database (http://www.funguild.org/query.php?qText=Vanderbylia&qDB=funguild_db&qField=taxon).

Figure S1. ANOVA analysis of seasonal (a) richness and (b) diversity indices of $PM_{2.5}$ bacterial and fungal communities. The rectangular box represents the interquartile range (IQR), with the bottom edge indicating the 25th percentile (Q1) and the top edge showing the 75th percentile (Q3) of the indices. The horizontal line inside the box represents the median value. The whiskers (vertical lines) extend from the box to the minimum and maximum ages within a 1.5 times IQR range. Any data points outside this range are depicted as individual dots, denoting potential outliers. The yellow diamond symbols denoted as superscript characters (e.g., 'a,' 'b,' 'c'), are used to indicate statistically significant differences between specific groups within the seasons.

Figure S2. Seasonal Spearman correlation between environmental factors and microbial communities at the genus level in: (a) Winter, (b) Spring, (c) Summer, and (d) Autumn. (DCAs, dicarboxylic acids; FAs, fatty acids; PAHs, poly aromatic hydrocarbons; B_, bacterial genus; F_, fungal genus; Increasing correlation coefficients is represented in the transition from black to red as showed by the x-axis of color key; The histogram represents the number of counts with a specific correlation coefficient; Star symbols indicate statistical significance level; ***, $p < 0.001$; **, $p < 0.01$; *, $p < 0.05$).

Figure S3. Information on temperature, bacterial and fungal Chao1 and Shannon index, OC/EC ratio, concentration of $PM_{2.5}$, DCAs, FAs, PAHs, sugars, and alkanes by sampling date in $PM_{2.5}$ samples.

Figure S4. Seasonal Spearman correlation analysis between the dominant bacterial genera and KEGG pathway in: (a) winter, (b) spring, (c) summer, and (d) autumn. Increasing correlation coefficients is represented in the transition from red to purple as indicated by the x-axis of the color key; The histogram represents the number of counts with a specific correlation coefficient; Star symbols indicate statistical significance level; ***, $p < 0.001$; **, $p < 0.01$; *, $p < 0.05$).

Table S1. Information on the environmental factors considered for the seasonal samples (Kang, 2021)

Type of environmental factors		Meteorologic data[a)]						Pollutant gas							Water-soluble ions								Organic matters[b)]				
Seasons	Date (yy-mm-dd)	T (℃)	P (hPa)	Rain (mm)	WS (m/s)	RH (%)	SR (Mj/m^2)	PM2.5 ($\mu g/m^3$)	O_3 (ppm)	NO_2 (ppb)	CO (ppm)	SO_2 (ppb)	OC ($\mu g/m^3$)	EC ($\mu g/m^3$)	SO_4^{2-} ($\mu g/m^3$)	NO_3^- ($\mu g/m^3$)	Cl^- ($\mu g/m^3$)	Na^+ ($\mu g/m^3$)	NH_4^+ ($\mu g/m^3$)	K^+ ($\mu g/m^3$)	Mg^{2+} ($\mu g/m^3$)	Ca^{2+} ($\mu g/m^3$)	DCAs (ng/m^3)	FAs (ng/m^3)	PAHs (ng/m^3)	Sugars (ng/m^3)	Alkane (ng/m^3))
Winter	2018-01-16	3.5	1007.6	0	0.7	59.1	2.4	81	0.006	89	1.2	6	10.53	1.81	7.68	31.03	1.36	1.23	13.35	0.42	0.04	0.14	314.63	278.54	48.18	694.58	77.72
	2018-01-17	4.5	1007.2	0	1.2	64.1	4.17	84	0.012	68	1.1	5	10.74	1.52	8.85	31.56	1.32	1.15	14.21	0.39	0.03	0.11	487.13	274.31	33.93	467.35	45.57
	2018-01-18	2.1	1012.9	0	1.9	59.6	n/a[c)]	64	0.015	54	0.9	5	9.49	1.41	9.57	19.10	1.08	1.14	10.90	0.38	0.03	0.10	258.18	219.84	16.20	698.95	36.21
	2018-01-19	1	1013.5	0	1.6	43	6.56	28	0.021	45	0.7	4	4.52	1.16	3.11	6.21	0.48	1.11	4.02	0.26	0.03	0.12	118.00	189.77	7.81	228.16	0.00
	2018-01-20	2.2	1012	0	1.6	57.6	4.51	66	0.017	61	1	6	7.92	1.43	8.68	19.15	1.18	1.20	10.04	0.37	0.04	0.14	392.94	268.15	37.32	1173.52	64.24
	2018-01-21	0.4	1012.7	0	1	36.6	5.88	26	0.018	45	0.7	4	5.70	0.95	4.00	9.70	0.50	1.12	5.46	0.28	0.03	0.10	62.17	174.12	6.25	335.84	23.63
	2018-01-22	0.2	1005.2	3.3	1.5	56.5	1.91	24	0.014	54	0.7	4	4.35	0.92	2.31	6.66	0.52	1.07	3.99	0.21	0.01	0.09	145.47	174.08	9.30	474.62	38.37
	2018-01-23	-11.7	1013.4	0	3.7	42	7.62	13	0.031	20	0.4	4	2.61	0.42	1.57	1.66	0.26	1.11	1.75	0.18	0.02	0.05	56.99	109.78	11.06	180.68	20.85
	2018-01-24	-14.2	1018.3	0	3.4	31.6	7.73	13	0.029	24	0.4	5	2.59	0.52	1.06	0.88	0.29	1.13	1.14	0.18	0.02	0.08	45.68	134.90	16.01	335.04	26.65
	2018-01-25	-14	1019.1	0	2.8	32.6	7.28	13	0.029	25	0.5	4	2.91	0.70	1.02	1.11	0.43	1.17	1.22	0.18	0.02	0.05	68.34	93.79	14.88	291.68	15.49
	2018-01-26	-14.8	1018.9	0	2.6	34.9	n/a	21	0.027	25	0.5	5	4.43	1.01	1.54	1.90	0.48	1.18	1.75	0.25	0.02	0.05	143.74	172.47	22.09	555.12	25.51
	2018-01-27	-9.9	1017.8	0	1.4	37.4	7.5	24	0.017	36	0.7	4	5.52	1.20	1.75	3.94	0.83	1.38	2.83	0.23	0.02	0.08	159.87	145.53	15.03	572.04	23.98
	2018-01-28	-6.3	1011.6	0	2.6	36	6.38	21	0.03	23	0.6	5	5.26	1.08	1.45	2.50	0.53	1.12	2.00	0.23	0.02	0.05	110.41	120.78	18.32	357.11	24.96
	2018-02-01	-4	1018.3	0	1.6	44.1	8.09	21	0.018	38	0.7	4	4.37	1.05	1.35	3.08	0.41	1.10	2.22	0.21	0.03	0.07	116.28	175.28	17.45	479.73	26.51
	2018-02-02	-2.4	1017.5	0	1.6	51.1	7.29	29	0.011	54	1	4	5.95	1.40	1.86	5.71	0.56	1.14	3.32	0.27	0.04	0.11	118.00	221.17	13.09	455.19	25.75
	2018-02-03	-7.3	1017.2	0.5	3.8	47	13.65	20	0.029	20	0.6	4	4.11	0.76	2.04	3.35	0.36	1.19	2.51	0.26	0.03	0.08	84.47	155.11	11.80	271.64	20.53
	2018-02-04	-9.5	1017.3	0	3.1	40.9	13.65	23	0.03	18	0.6	4	4.58	0.71	2.81	2.11	0.23	1.17	2.29	0.26	0.02	0.06	88.39	141.97	9.59	248.99	15.09
	2018-02-06	-10.1	1014.4	0	3.1	36.5	14.13	21	0.029	20	0.6	4	4.18	0.70	1.96	1.66	0.23	0.36	1.43	0.29	0.02	0.00	113.58	151.41	21.53	328.43	16.44
	2018-02-07	-8	1015.4	0	1.5	39.8	13.39	24	0.019	36	0.7	4	4.96	0.93	1.51	2.07	0.33	0.60	1.51	0.21	0.03	0.27	108.49	175.84	12.36	375.54	22.05
	2018-02-08	-4.4	1014	0	1.2	43.3	13.05	33	0.013	50	0.9	4	11.90	1.14	2.22	6.33	0.52	0.40	3.43	0.19	0.01	0.00	118.10	215.23	9.84	313.09	28.98
Spring	2018-03-16	7.1	1014.1	0	1.9	46.9	21.16	6	0.035	17	0.1	2	1.52	0.29	2.48	1.22	0.52	0.67	0.92	0.08	0.02	0.03	45.48	106.97	1.65	100.68	20.66
	2018-03-17	6.6	1016.6	0	1.5	48	17.87	20	0.028	26	0.2	3	4.92	0.59	3.93	13.01	0.55	0.57	4.68	0.10	0.02	0.04	118.79	166.64	2.57	278.68	13.31
	2018-03-18	8.2	1010.7	0.5	1.2	55.9	7.19	44	0.025	35	0.4	4	8.56	0.88	5.11	22.82	0.65	0.43	7.69	0.17	0.01	0.03	201.63	273.46	4.99	679.29	34.97
	2018-03-19	8	1006.2	1	2.5	64.5	3.33	26	0.034	19	0.2	3	2.12	0.21	3.86	1.05	0.35	0.58	1.15	0.10	0.02	0.02	55.39	71.25	0.93	7.36	5.03
	2018-03-20	4.7	1013	0	3.4	39.9	14.36	7	0.047	9	0.1	2	1.07	0.16	2.41	0.42	0.57	0.67	0.59	0.07	0.02	0.02	25.37	70.43	0.86	25.48	5.78
	2018-03-21	2.1	1007.5	1	1.7	64.1	6.13	7	0.038	17	0.1	2	2.49	0.38	1.77	3.21	0.34	1.16	1.84	0.25	0.02	0.05	46.85	104.66	1.45	171.15	9.76
	2018-03-22	4.9	1004.4	0	2.2	61.5	20.45	30	0.03	31	0.3	4	6.89	0.73	4.31	15.44	0.63	1.64	6.85	0.67	0.07	0.14	178.95	157.00	2.75	197.98	19.18
	2018-03-23	6.1	1009.1	0	2	55.3	19.08	56	0.029	41	0.4	5	8.32	0.83	6.81	26.85	0.85	1.66	10.97	0.73	0.06	0.18	174.60	174.35	2.74	123.41	20.51
	2018-03-24	7.6	1011.8	0	2.1	61.9	15.35	89	0.034	45	0.7	6	10.25	0.81	23.85	32.48	0.74	1.70	17.64	0.72	0.04	0.15	715.40	185.47	1.91	145.58	31.43
	2018-03-25	9.6	1014	0	1.7	65.6	19.12	108	0.04	37	0.8	5	9.78	1.47	27.60	31.07	0.56	1.62	18.47	0.66	0.04	0.18	479.91	201.16	2.34	192.07	18.18
	2018-03-26	11	1011.3	0	1.9	64.5	19.06	85	0.025	50	0.7	5	5.81	0.98	15.32	13.90	0.29	1.61	9.78	0.54	0.07	0.37	122.76	141.11	1.58	73.90	12.24
	2018-03-27	13.3	1007.3	0	1.6	61.1	15.98	63	0.036	44	0.6	6	6.39	0.86	12.60	19.57	0.47	1.64	10.74	0.53	0.06	0.28	196.45	149.96	1.93	88.89	13.92
	2018-03-28	14	1006.6	0	2.2	66.4	13.94	38	0.034	31	0.4	5	3.36	0.71	11.38	8.24	0.32	1.59	7.12	0.44	0.04	0.18	93.73	141.96	1.42	87.16	60.65
	2018-03-29	15.4	1009.6	0	1.6	66.3	14.86	46	0.027	31	0.4	4	6.09	0.93	11.21	11.42	0.33	1.85	7.98	0.48	0.04	0.17	151.72	162.40	1.56	291.42	14.67
	2018-03-30	14.8	1012.7	0	1.7	55.6	20.01	39	0.032	30	0.3	4	5.50	0.66	4.75	6.94	0.41	1.85	4.22	0.47	0.05	0.18	161.85	160.87	1.09	131.01	12.81
	2018-03-31	14	1009.9	0	1.9	52.9	17.08	28	0.034	32	0.3	4	5.69	0.61	2.88	5.74	0.43	1.96	2.90	0.49	0.07	0.16	115.85	167.75	1.17	140.94	11.21
	2018-04-01	15.6	1006.3	0	1.5	68.8	7.25	35	0.032	25	0.3	5	4.00	0.52	7.56	3.79	0.84	1.90	4.36	0.41	0.08	0.21	141.88	125.80	0.91	96.69	7.64
	2018-04-02	18.4	1005.4	0	1.9	64	14.14	28	0.033	25	0.3	5	2.86	0.56	5.56	3.16	1.15	3.41	2.93	0.52	0.12	0.28	66.97	196.01	0.64	36.60	6.52
	2018-04-04	13.4	1007.4	18.5	1.9	67	19.56	7	0.034	14	0.1	3	1.29	0.17	0.38	0.80	0.11	1.71	0.94	0.40	0.01	0.05	46.66	92.15	0.87	68.09	6.33

	2018-04-05	7.6	1005.7	10.5	2	90.6	2.15	5	0.03	16	0.1	2	1.28	0.22	0.52	1.68	0.12	1.63	1.31	0.38	0.01	0.03	16.81	66.16	0.39	33.78	4.10
	2018-08-20	29.1	995.3	0	5.1	55.6	15.07	28	0.044	23	0.3	4	1.98	0.31	6.49	1.23	0.12	0.32	2.05	0.04	0.03	0.04	89.05	153.61	1.44	16.21	11.24
	2018-08-21	26.6	993.9	5	7.1	71.4	12.86	17	0.034	17	0.3	4	2.04	0.49	2.14	1.34	0.04	0.18	0.42	0.03	0.02	0.02	40.38	88.30	0.69	25.88	4.13
	2018-08-22	30.7	994.7	n/a	3.2	54.1	22.27	19	0.032	17	0.3	3	1.34	0.23	2.03	1.19	0.10	0.38	0.27	0.02	0.04	0.01	41.14	127.82	0.65	15.61	8.15
	2018-08-25	25.2	999.2	n/a	5.3	68	16.2	19	0.042	15	0.4	4	1.11	0.27	2.65	1.16	0.02	0.13	0.60	0.04	0.02	0.01	0.00	0.00	n/a	0.00	n/a
	2018-08-27	22.7	1001.6	19.5	2.1	91	7.84	10	0.023	14	0.4	3	0.54	0.33	0.32	0.38	0.00	0.00	0.01	0.00	0.00	0.00	24.69	52.69	0.32	18.13	2.27
	2018-08-28	23.7	1001.5	96.5	3.7	92.4	4.42	10	0.009	16	0.4	3	0.57	0.40	0.44	0.34	0.01	0.00	0.00	0.00	0.00	0.01	16.74	69.64	0.53	11.37	3.25
	2018-08-29	25.2	999.1	42	4.5	86	2.75	12	0.01	15	0.3	3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	18.68	85.35	0.66	7.94	4.47
	2018-08-30	25.3	999.2	9.5	3.7	80.9	8.74	23	0.029	21	0.5	4	n/a	n/a	6.48	1.93	0.05	0.13	2.82	0.07	0.02	0.03	73.55	117.86	0.81	40.65	8.24
	2018-08-31	25.6	1000.3	0.1	3.7	67.4	22.17	20	0.037	18	0.4	4	2.08	0.35	1.84	0.64	0.02	0.05	0.69	0.07	0.01	0.01	65.65	148.45	2.68	58.97	8.04
	2018-09-01	25.5	1001.5	n/a	2.3	59.4	21.01	13	0.031	12	0.4	3	0.60	0.13	0.96	0.30	0.03	0.08	0.24	0.02	0.01	0.00	42.03	108.64	0.37	18.57	5.76
Summer	2018-09-02	25.1	999.2	n/a	2.8	55.8	20.34	12	0.039	13	0.3	3	1.27	0.28	1.21	0.59	0.04	0.08	0.37	0.02	0.01	0.01	55.63	109.10	0.54	55.66	6.29
	2018-09-03	23.3	991.9	34.5	5.5	85.3	3.36	14	0.021	20	0.4	4	0.89	0.43	1.32	1.97	0.10	0.02	0.93	0.01	0.01	0.03	36.96	104.35	0.44	35.32	7.93
	2018-09-04	23.2	988	n/a	5.2	69.4	21.64	14	0.034	11	0.3	3	0.94	0.22	1.46	0.46	0.04	0.03	0.46	0.04	0.03	0.01	55.21	137.66	0.84	58.83	11.27
	2018-09-05	24	992.9	n/a	5.7	63.5	22.46	16	0.044	15	0.4	4	1.95	0.43	3.15	2.94	0.10	0.14	1.75	0.06	0.02	0.03	90.56	118.73	0.94	22.77	8.99
	2018-09-06	24.1	994.2	1	5	69.9	11.03	26	0.045	24	0.5	5	2.17	0.43	4.43	1.62	0.11	0.15	1.78	0.07	0.03	0.05	88.17	130.28	0.83	25.85	9.90
	2018-09-07	22	995.7	0.5	4.3	54.6	19.58	18	0.044	14	0.4	4	1.07	0.29	1.21	0.58	0.03	0.07	0.24	0.05	0.05	0.03	56.66	96.16	1.23	61.01	5.69
	2018-09-09	22.2	1006.4	n/a	2.8	49	21.4	13	0.035	15	0.4	4	0.82	0.23	0.97	0.30	0.08	0.11	0.14	0.03	0.01	0.00	47.88	64.11	0.36	24.49	5.69
	2018-09-10	22.9	1010.6	n/a	2.7	49.5	19.84	8	0.037	10	0.3	3	0.46	0.20	0.74	0.27	0.04	0.13	0.02	0.01	0.01	0.00	41.40	67.01	0.38	17.66	6.88
	2018-09-11	21.6	1010.8	n/a	2.4	48.1	17.85	8	0.032	13	0.3	3	0.62	0.24	0.89	0.25	0.03	0.10	0.02	0.01	0.01	0.00	40.47	73.92	0.39	19.75	6.40
	2018-09-12	22.8	1008.1	n/a	3.2	52	20.39	11	0.035	19	0.3	3	1.21	0.33	1.34	0.67	0.05	0.21	0.22	0.02	0.02	0.00	47.64	92.01	0.38	31.16	6.17
	2018-11-05	11.9	1012.9	0	1.1	65.5	11.09	43	0.013	42	1.1	4	7.25	1.15	6.08	11.99	0.28	0.03	7.23	0.24	0.01	0.07	210.62	201.07	2.64	368.25	22.84
	2018-11-06	12.2	1014.7	0	0.9	70.5	7.85	89	0.006	63	1.1	5	12.24	1.52	9.86	30.44	0.72	0.07	14.39	0.36	0.02	0.08	346.16	258.53	4.74	540.24	33.14
	2018-11-07	12.8	1014	2	1.1	79.5	4.05	62	0.014	34	0.7	4	3.34	0.61	3.17	8.96	0.29	0.03	5.31	0.09	0.00	0.02	123.17	78.28	0.62	150.39	7.81
	2018-11-08	11.8	1002.5	64	1.8	93.8	1.31	9	0.027	16	0.4	4	0.80	0.13	1.63	1.15	0.23	0.11	1.69	0.04	0.02	0.01	29.17	51.85	0.88	49.76	3.39
	2018-11-09	12.1	1006.9	1	3.1	69	9.75	34	0.036	20	0.6	5	4.75	0.57	5.38	9.58	0.69	0.25	5.99	0.19	0.05	0.06	158.67	131.97	1.86	166.25	11.00
	2018-11-10	11.9	1013.4	0	1.4	69.1	11.14	61	0.026	30	0.8	5	5.91	0.60	9.98	16.69	0.68	0.16	10.07	0.24	0.04	0.13	176.09	140.39	2.62	205.47	14.71
	2018-11-11	8.1	1011.9	0	1.1	67.6	3.72	45	0.017	28	0.8	4	4.01	0.44	1.68	3.58	0.19	0.00	1.99	0.09	0.02	0.07	90.24	141.47	6.22	307.16	18.05
Autumn	2018-11-12	8.1	1009.6	0	1.2	52.3	12.12	21	0.018	29	0.6	5	5.30	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	157.02	161.03	2.89	355.63	21.96
	2018-11-13	8.8	1009.6	0	1.1	51.6	11.7	26	0.012	40	0.8	4	4.73	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	89.37	146.41	2.02	248.90	15.78
	2018-11-14	9.8	1012.9	0	1.1	55.5	11.61	25	0.013	39	0.7	4	3.49	0.57	2.10	8.64	0.14	0.06	3.56	0.10	0.01	0.03	113.82	145.02	0.97	216.33	25.05
	2018-11-15	9.7	1014.2	0	1	55.4	9.55	37	0.012	45	0.7	4	6.13	1.18	2.39	19.87	0.17	0.05	6.72	0.11	0.01	0.03	135.18	169.04	1.27	258.49	17.84
	2018-11-16	8.8	1011.6	0	1.7	65.1	8.28	47	0.017	36	0.9	4	5.56	0.84	5.84	9.17	0.20	0.04	4.87	0.17	0.01	0.02	163.59	134.12	3.32	438.81	14.28
	2018-11-17	4.9	1013.1	0	1.4	50.8	9.17	23	0.014	27	0.7	4	4.58	0.88	1.09	3.16	0.17	0.03	1.14	0.13	0.01	0.04	90.11	166.13	5.54	486.48	26.10
	2018-11-18	6.1	1011.2	0	1.1	48.8	7.49	22	0.015	29	0.8	4	4.53	0.86	2.24	10.74	0.24	0.06	3.75	0.16	0.01	0.03	84.44	144.49	2.50	229.57	15.15
	2018-11-19	6.5	1012.2	0	1.4	50.4	7.83	40	0.012	41	1	5	4.79	0.84	3.34	10.89	0.27	0.07	4.05	0.16	0.01	0.06	88.58	123.11	4.08	262.12	16.30

[a] T, temperature; P, air pressure; WS, wind speed; RH, relative humidity; Rain, precipitation

[b] DCAs, dicarboxylic acids; FAs, fatty acids; PAHs, poly aromatic hydrocarbons

[c] n/a, no available information

Table S2. Seasonal OTUs and α-diversity indices of the bacterial and fungal communities in the $PM_{2.5}$ samples

Microbial community	Seasons	OTUs[a)]	Chao1[b)]	Shannon[c)]	Gini-Simpson[d)]	Good's Coverage[e)]
Bacterial community	Winter	219	243	5.15	0.91	0.99734
	Spring	309	348	3.81	0.75	0.99870
	Summer	44	57	2.40	0.73	0.99985
	Autumn	87	128	3.45	0.81	0.99967
fungal community	Winter	188	203	2.22	0.56	0.99956
	Spring	193	235	2.99	0.70	0.99944
	Summer	13	16	0.50	0.13	0.99998
	Autumn	21	24	0.76	0.23	0.99997

[a)] Operational taxonomic units (OTUs) show the number of observed species generated for each sample.

[b)] The Chao1 index estimates species richness, which is the total number of species in a community, using the frequency of appearance of rarer OTUs.

[c)] The Shannon index measures the number of different species and represents how evenly the basic individuals are distributed among those species.

[d)] The Inversed Simpson index indicates how evenly the species are distributed and considers the degree of concentration classified into species.

[e)] Good's Coverage considers the number of taxonomic units sampled more than once, divided by the total number of units sampled. It measures the total number of species in a sample.

Table S3. Trophic mode and guild of the dominant fungi at the genus level parsed using FUNGuild database (http://www.funguild.org/query.php?qText=Vanderbylia&qDB=funguild_db&qField=taxon).

Fungal genus	Dominant seasons	Trophic mode	Guild	Confidence Ranking	Growth form	Note
Candida	Winter, summer, autumn	Pathotroph, Saprotroph, Symbiotroph	Animal Pathogen, Endophyte, Endosymbiont, Epiphyte, Soil Saprotroph, Undefined Saprotroph	Probable	Dimorphic Yeast	-
Epicoccum	Winter, summer, autumn	Pathotroph, Saprotroph, Symbiotroph	Endophyte, Fungal Parasite-Lichen Parasite, Plant Pathogen, Wood Saprotroph	Probable	Microfungus	-
Alternaria	Winter, summer, autumn	Pathotroph, Saprotroph, Symbiotroph	Animal Pathogen, Endophyte, Plant Pathogen, Wood Saprotroph	Possible	Microfungus	-
Cutaneotrichosporon	Winter, summer, autumn	Pathotroph	Animal Pathogen	Possible	Yeast	Pathogenic to humans
Aureobasidium	Winter, summer, autumn	Pathotroph, Saprotroph, Symbiotroph	Animal Pathogen, Endophyte, Epiphyte, Plant Pathogen, Undefined Saprotroph	Possible	Facultative Yeast	-
Fusarium	Winter	Pathotroph, Saprotroph, Symbiotroph	Animal Pathogen, Endophyte, Lichen Parasite, Plant Pathogen, Soil Saprotroph, Wood Saprotroph	Possible	Microfungus	Likely opportunistic human pathogen
Calvatia	Spring	Saprotroph	Soil Saprotroph	Probable	Gasteroid	Common name - puffball
Asterophora	Spring	Pathotroph	Fungal Parasite	Highly Probable	-	-
Scorias	Spring	Saprotroph	Undefined Saprotroph	Probable	Microfungus	-
Crustoderma	Spring	Saprotroph	Wood Saprotroph	Probable	Corticioid	-
Ctenomyces	Spring	Saprotroph	Dung Saprotroph, Undefined Saprotroph	Highly Probable	-	-
Radulomyces	Spring	Saprotroph	Undefined Saprotroph	Probable	-	-

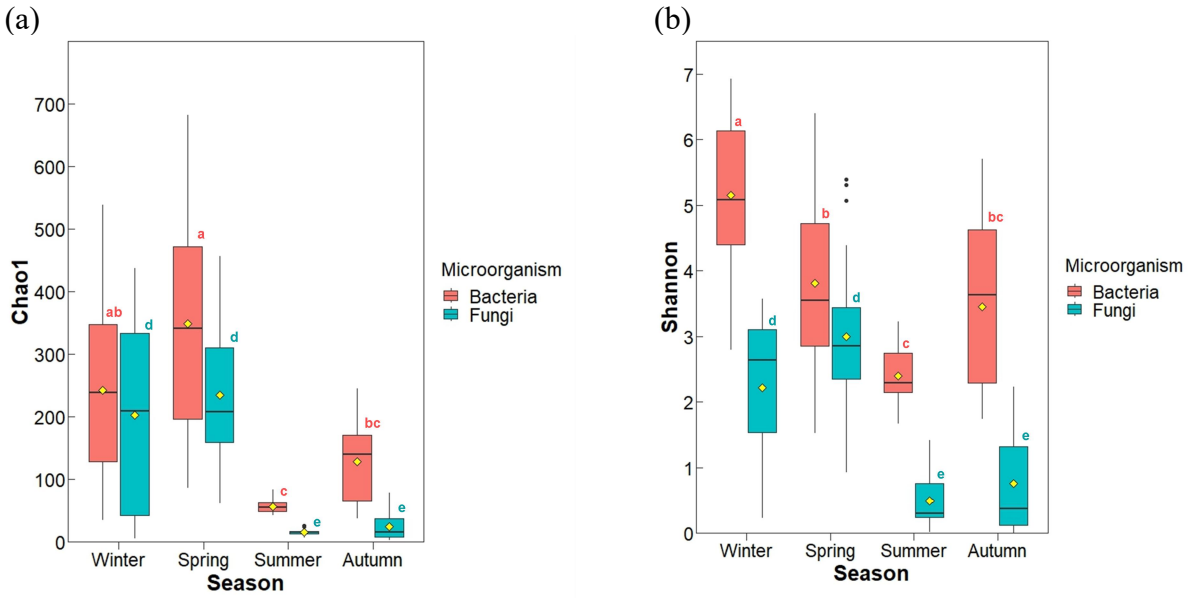

Figure S1. ANOVA analysis of seasonal (a) richness and (b) diversity indices of $PM_{2.5}$ bacterial and fungal communities. The rectangular box represents the interquartile range (IQR), with the bottom edge indicating the 25th percentile (Q1) and the top edge showing the 75th percentile (Q3) of the indices. The horizontal line inside the box represents the median value. The whiskers (vertical lines) extend from the box to the minimum and maximum ages within a 1.5 times IQR range. Any data points outside this range are depicted as individual dots, denoting potential outliers. The yellow diamond symbols denoted as superscript characters (e.g., 'a,' 'b,' 'c'), are used to indicate statistically significant differences between specific groups within the seasons.

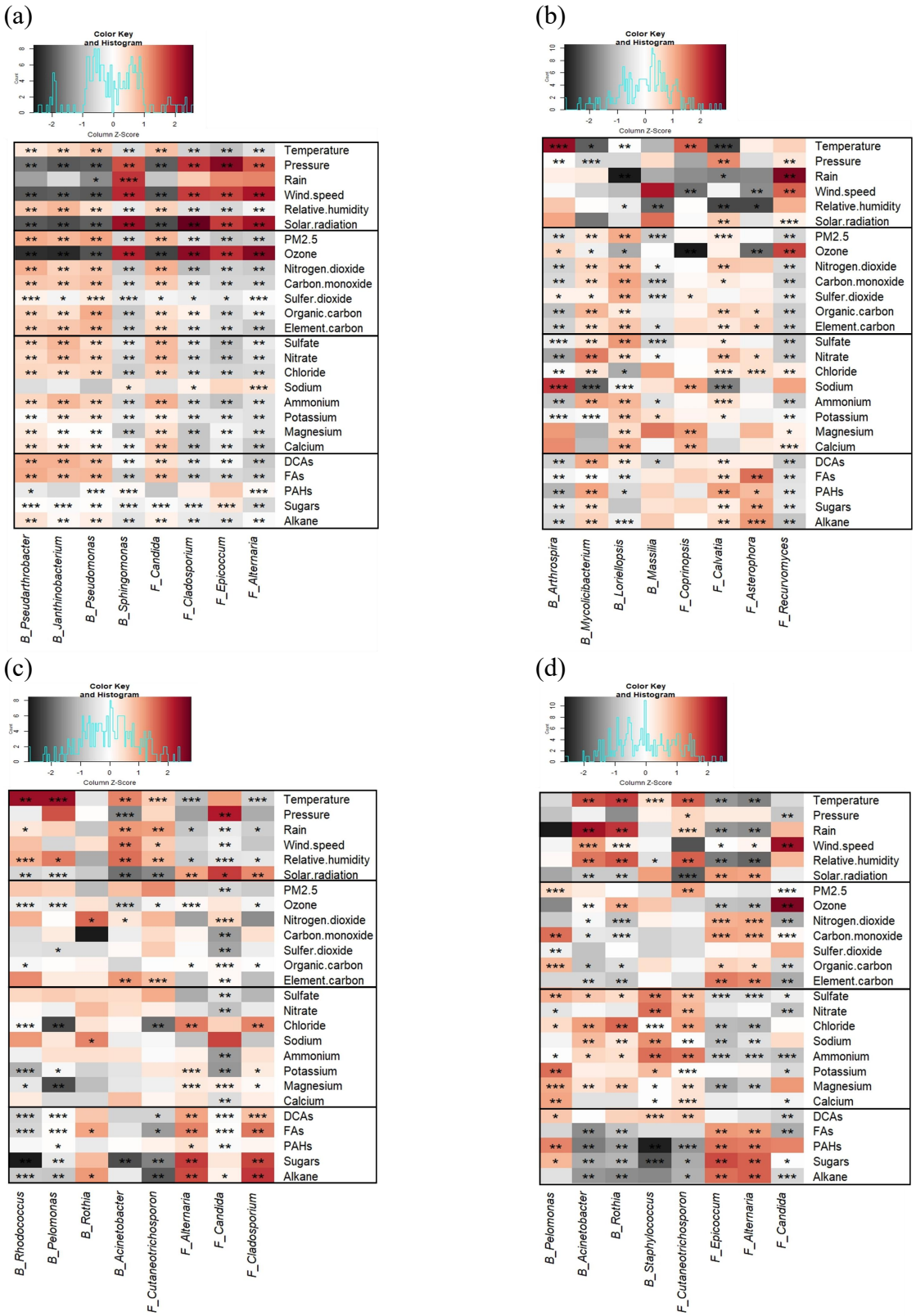

Figure S2. Seasonal Spearman correlation between environmental factors and microbial communities at the genus level in: (a) Winter, (b) Spring, (c) Summer, and (d) Autumn. (DCAs, dicarboxylic acids; FAs, fatty acids; PAHs, poly aromatic hydrocarbons; B_, bacterial genus; F_, fungal genus; Increasing correlation coefficients is represented in the transition from black to red as showed by the x-axis of color key; The histogram represents the number of counts with a specific correlation coefficient; Star symbols indicate statistical significance level; ***, $p < 0.001$; **, $p < 0.01$; *, $p < 0.05$).

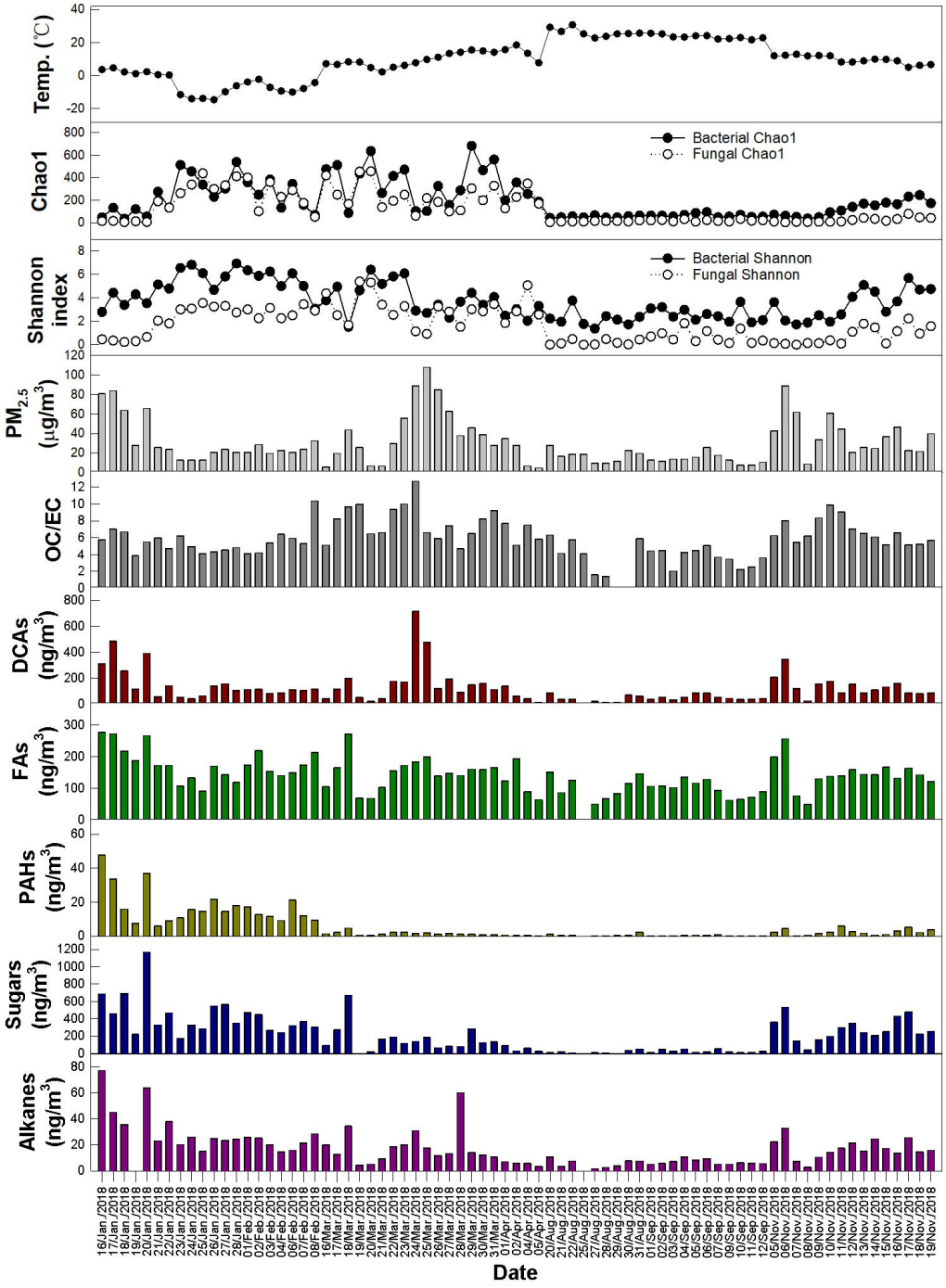

Figure S3. Information on temperature, bacterial and fungal Chao1 and Shannon index, OC/EC ratio, concentration of $PM_{2.5}$, DCAs, FAs, PAHs, sugars, and alkanes by sampling date in $PM_{2.5}$ samples.

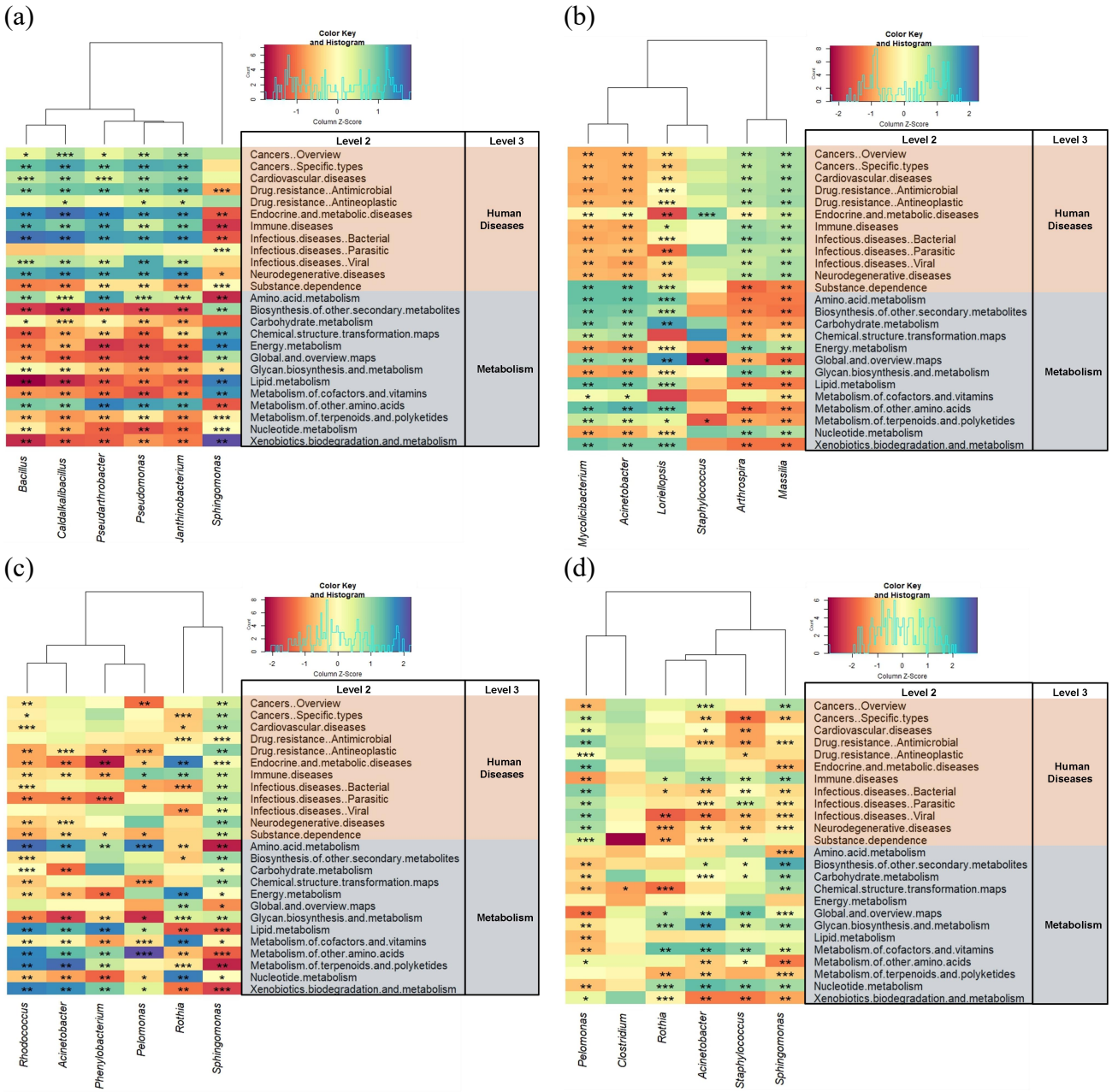

Figure S4. Seasonal Spearman correlation analysis between the dominant bacterial genera and KEGG pathway in: (a) winter, (b) spring, (c) summer, and (d) autumn. Increasing correlation coefficients is represented in the transition from red to purple as indicated by the x-axis of the color key; The histogram represents the number of counts with a specific correlation coefficient; Star symbols indicate statistical significance level; ***, $p < 0.001$; **, $p < 0.01$; *, $p < 0.05$).