MEASUREMENTS OF ELEMENTAL CARBON (EC) AND ORGANIC CARBON (OC) IN $PM_{2.5}$

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Olca Simay Nalçacı, Beril Akman, Ceren Yiğit, Rosa M Flores
Environmental Engineering Department, Marmara University, Istanbul, Turkey

I. THEOROTICAL BACKGROUND

AIR POLLUTION AND SOURCES

Air pollution is the pollution of the air due to the presence in the atmosphere of substances harmful to the health of living things or harmful to the climate. Air pollution is caused by solid, liquid particles and certain gases suspended in the air. These solid and liquid particles suspended in the air are called aerosols.

Particulate matter (PM) is a common term for a suspension of solid and liquid particles in the air. Fine particles are defined as particles with a diameter of 2.5 m or less (also known as $PM_{2.5}$). This group of particles also includes ultrafine and nanoparticles, which have diameters smaller than 0.1 m. Coarse particles are defined as particles having a diameter of more than 2.5 m but less than or equal to 10 m

EFFECTS OF ON HUMAN HEALTH AND ECOSYSTEM

The potential for particles to cause health problems is directly proportional to their size. Small particles with a diameter of smaller than 10 micrometers cause the most issues since they can go deep into your lungs and even into your bloodstream. Freshwater snails were found to be negatively affected by $PM_{2.5}$ exposure.

Area of study:

The sampling site is located in Beşiktaş, Barbaros Boulevard. Beşiktaş is a very crowded and touristic district of Istanbul. Barbaros Boulevard, with its historical and touristic areas, workplaces, shopping areas, cafes, restaurants, educational areas, and as a main road where public transportation continues for most of the day, is in heavy traffic. Connecting two continents is also one of the reasons for this density, and it constantly receives emissions from ships and planes. And In sampling, the data is taken in Barbaros Street in Beşiktaş at a 5 m elevation from the ground. In addition, although the use of natural gas has become widespread, low quality fuels are still used.

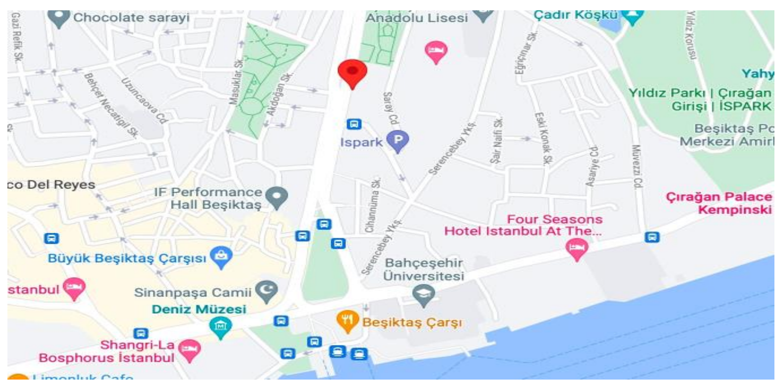

Figure 1. The Location of the Sampling Site (Maps, 2022)

II. SAMPLING AND MEASUREMENT

- **SAMPLING METHOD**

In sampling TE-PNY1123 Mass Flow Controlled PUF High Volume Air Sampler is used. The samples are taken in 2-hour intervals from 7am to 7pm and during the nighttime the samples are taken in 12-hour intervals this concludes to 7 samples each day. The samples are collected for one week for each season, with exception of winter which requires 3-week sample collection.

At the end of the sampling period, the frame is removed to expose the filter and the exposed filter is removed from the support screen by holding it by its ends (not the corners). The filter is folded lengthwise so that the sample touches the sample. The 6" Roller Piece is removed, and the sample is collected.

- **MEASUREMENT**

Sunset laboratory thermal-optical carbon analyzer was used to do the experiment to measure the OC and EC concentrations. The sucrose solution was analyzed daily, and these data obtained are used as a calibration mark, then the experiment is done at high temperatures to expose the EC and OC concentrations of the acquired samples. (Wang et al., 2021).

First, the values of the gases connected to the device are adjusted to the desired level. To determine the normal carbon level, a sucrose solution is made with the device. An equal amount of sucrose sample is added to the filters placed in the device and measurements are made with equal time. This process is repeated until an average value is obtained. After obtaining an average value, the normal carbon value in the device is adjusted according to the value obtained with sucrose. Next, preparation is made for sample measurements. Each sample result is given a sequential name and the results obtained are noted.

III. RESULTS

Table 1. Hourly statistics during sampling campaigns

Seasons	Value	Traffic	Air Pressure (mbar)	Temperature (C°)	Moisture (%)	Wind Speed (m/s)	Wind Direction (°)	BLH (m)
Winter1	7	3779.86	1023.1	5.15	54.9	1.5		419
	9	5435.86	1023.3	5.61	54.7	1.7	228.2	477
	11	5977.79	1023.9	6.42	56.4	2.1	226.6	602
	13	5692.36	1023.8	7.04	55.3	2.9	239.5	683
	15	5507.29	1022.8	7.95	51.3	3.3		715
	17	4378.86	1022.4	8.26	51.2	2.8	226.6	613
	19	8034.29	1022.3	7.42	54.8	2.0	194.5	492
Winter 2	7	2712.86	1032.4	4.17	61.7	0.3	73.9	268
	9	4691.43	1033.1	4.80	60.6	0.3	88.4	308
	11	5143.57	1033.3	6.96	54.6	0.8	96.4	479
	13	4927.71	1033.3	8.51	51.2	1.0	120.5	573
	15	4529.29	1032.6	9.84	48.6	1.1	127.0	586
	17	2910.00	1032.3	9.99	49.1	1.0	109.3	530
	19	6005.43	1031.7	6.31	57.9	0.4	84.2	434
Spring	7	2324.50	1014.7	15.57	53.3	0.4	132.2	155
	9	2746.00	1015.3	17.44	48.4	0.9	150.5	217
	11	2710.38	1015.9	19.25	44.9	1.2	140.6	422
	13	2736.13	1016.0	20.94	42.6	1.4	154.7	542
	15	2236.75	1015.7	22.54	39.2	1.6	111.1	577
	17	2295.00	1015.1	22.61	38.9	1.6	120.9	471
	19	4298.13	1014.4	17.78	49.3	0.6	132.7	345
Summer	7	3329.00	1012.8	24.01	53.3	0.3		337
	9	4094.29	1013.3	26.36	48.2	0.7		472
	11	3936.00	1013.6	28.50	44.2	1.2	172.0	750
	13	3327.43	1013.5	30.17	37.6	1.3		913
	15	2999.00	1013.4	31.09	36.1	1.5		958
	17	2957.00	1013.1	31.04	36.8	1.6		736
	19	15535.57	1012.8	25.88	48.1	0.7	75.8	566
Fall	7	3440.14	1025.5	12.79	62.4	0.3	155.9	470
	9	2494.86	1026.1	13.46	60.2	0.6	146.3	486
	11	2561.29	1026.2	14.34	57.4	1.0	141.4	570
	13	3094.00	1025.9	15.53	54.4	1.0	173.6	630
	15	3681.14	1025.1	16.64	51.3	1.1	135.0	669
	17	3055.57	1025.0	14.97	56.3	1.0	143.0	608
	19	16115.57	1025.7	12.51	62.1	0.7	109.0	581
Winter 3	7	5337.14	1025.6	5.74	85.6	1.7	161.8	524
	9	5853.00	1026.2	6.33	83.4	2.0	134.4	544
	11	6234.71	1026.6	7.76	75.8	2.3	211.6	707
	13	6058.86	1026.4	8.29	73.1	2.6	191.5	805
	15	6874.86	1025.7	8.65	69.6	2.4	212.4	836
	17	5809.14	1025.8	8.61	70.5	2.0	217.0	725
	19	25102.57	1026.3	6.85	81.2	1.5	201.6	611

For this project there were 6 main sampling campaigns throughout the year. Which are named by seasons and since there were 3 different samplings done for the winter season , numberings were added after the season. Samplings dates are given below ;

- Winter 1 - 18/01/2021 - 24/01/2021
- Winter 2 - 20/02/2021 - 26/02/2021
- Spring - 28/04/2021- 05/05/2021
- Summer - 04/08/2021 -10/08/2021
- Fall - 05/11/2021 -11/11/2021
- Winter 3 - 09/02/2022- 15/02/2022

For these seasonal variations , the data was taken from Beşiktaş until November 2021 ,after that these data were obtained from Çatladıkapı location due to data unavailability in Beşiktaş location.

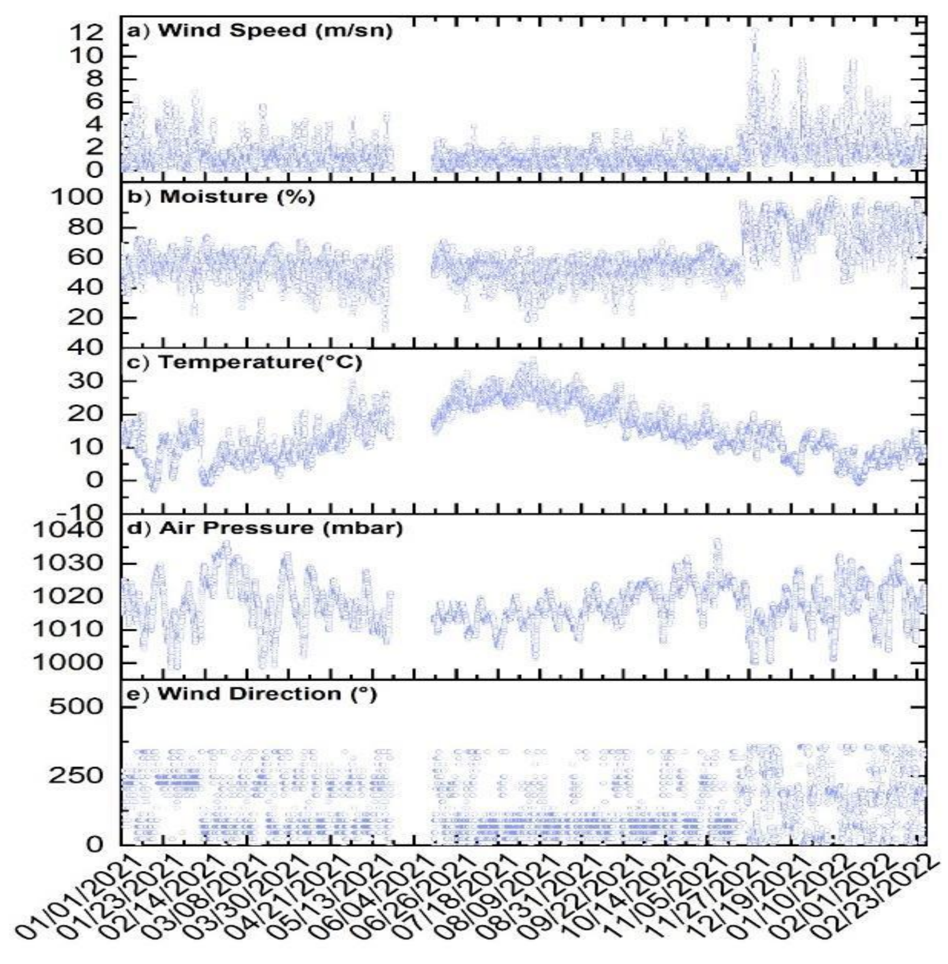

Figure 2. Time series of meteorological data in Beşiktas-IBB from 01/01/2020 to 15/05/2021 and Catladikapi-IBB from 01/01/2020 to 15/05/2021

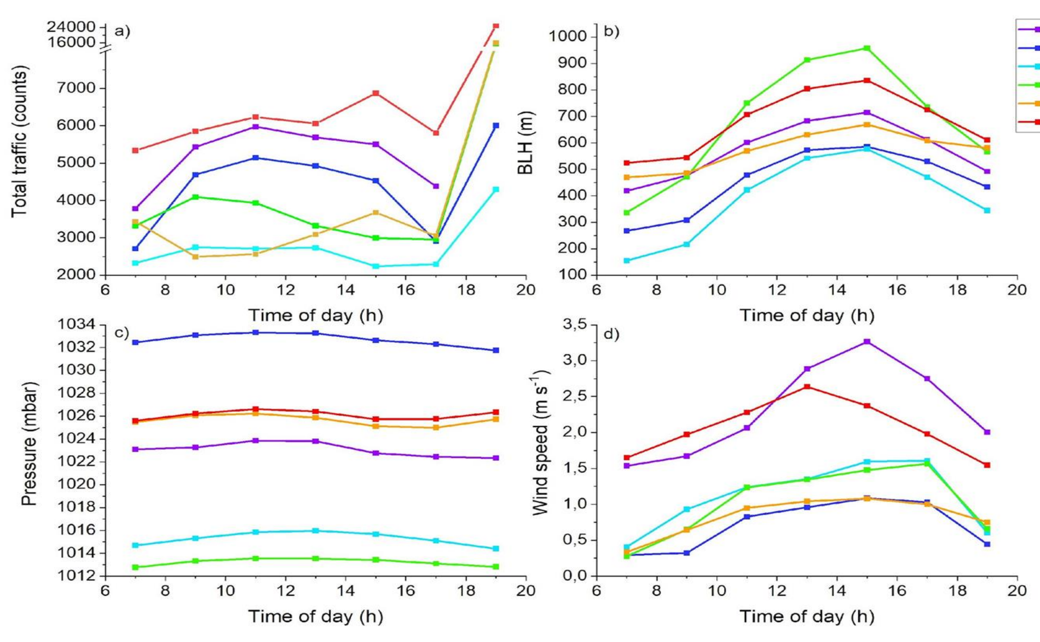

Figure 3. Hourly data of total traffic, BHL, pressure and wind speed

Table 2. Comparison of OC and EC Concentrations Seasonally in Megacities

Megacities	Population	Elemental Carbon (µg/m3) Winter	Elemental Carbon (µg/m3) Summer	Organic Carbon (µg/m3) Winter	Organic Carbon (µg/m3) Summer	Time	References
Guangzhou, China	46700000	7.9 ±5.3	6.4 ±2.0	19.7 ± 8.5	15.8 ±2.1	2012	(Cao et al., 2012)
Tokyo, Japan	40400000	5.5	3.3	8.9	5.1	2019	(Hayami et al., 2019)
Shanghai, China	33600000	3	2	8.1	6.8	2013	(Chang et al., 2017)
Delhi, India	30300000	11±7	N/A	23± 16	N/A	2010	(Amin et al., 2021)
Manila, Philippines	25700000	0.67 ±0.19	0.5 ±0.09	1.18 ± 0.62	0.93±0.61	2018	(Bagtasa et al., 2018)
Seoul, South Korea	24800000	2	1.4	5.2	3.6	2014	(Park et al., 2015)
Beijing, China	19800000	7.8	6.9	43.2	15.4	2005	(Yang et al., 2005)
Istanbul, Turkey	16000000	4	5.5	10.5	7.3	2018	(Flores et al., 2020)
Istanbul, Turkey	16000000	3.16	4.82	13.55	15.25	2022	

When comparing the data across the world, Tokyo, Japan and Guangzhou, China have adjacent concentrations with Istanbul. However as seen in Table 2 the data for Guangzhou was in 2012 which cannot be compared. Thus Tokyo has the most compatible results with Istanbul.

Table 3. Minimum, average, and maximum values during various sampling campaigns

Seasons	Value	Traffic	Air Pressure (mbar)	Temperature (C°)	Moisture (%)	Wind Speed (m/s)	Wind Direction (°)
Winter 1 2021	Min	16.00	1009	-3.2	44.8	0	45
	Avg	1675.4	1022.77	7.08	54.39	2.18	221.00
	Max	4425.0	1030	13.9	67.5	5.9	337.5
Winter 2 2021	Min	3	1022.3	1	41.8	0	0
	Avg	1442.95	1032.29	6.84	56.10	0.60	93.68
	Max	4350	1036.7	15.3	67.8	1.8	337.5
Spring 2021	Min	63	1010	10.6	22	0	22.5
	Avg	806.12	1014.92	18.75	46.94	0.89	135.97
	Max	2972	1019	29.9	63.2	4.6	337.5
Summer 2021	Min	116	1001.2	21.2	19.3	0	0
	Avg	1516.46	1013.06	27.21	45.42	0.88	103.18
	Max	3501	1019	36.8	66	2.9	337.5
Fall 2021	Min	118	1017	8.4	40.8	0	0
	Avg	1488.26	1025.69	13.56	59.55	0.80	130.39
	Max	3636	1037	20.4	70	1.8	337.5
Winter 3 2022	Min	0	1020.2	3.7	50.9	0.4	6.5
	Avg	0	1026.20	7.21	78.76	1.85	194.93
	Max	0	1032.2	11.8	95.4	3.7	358.1

Table 3 shows that minimum, average, and maximum values during various sampling campaigns and it shows; winter 1: -3.2-13.9 C, winter 2: 1-15.3 C, spring: 10.6-29.9 C, summer: 21.2-36.8 C, fall: 8.4-20.4 C, and winter 3: 3.7-11.8 C were the average daily temperature ranges during the sampling campaign. 7.08, 6.84, 18.75, 27.21, 13.56, and 7.21 were the seasonal averages, respectively. The relative humidity decreases as the temperature increases, reaching its lowest point about 15:00 in every sampling campaign according to Table 4.. During all seasons, the average daily relative humidity remained generally high and stable, with the lowest values in the summer (19.3%) and the highest values in the winter 3 (95.4%).

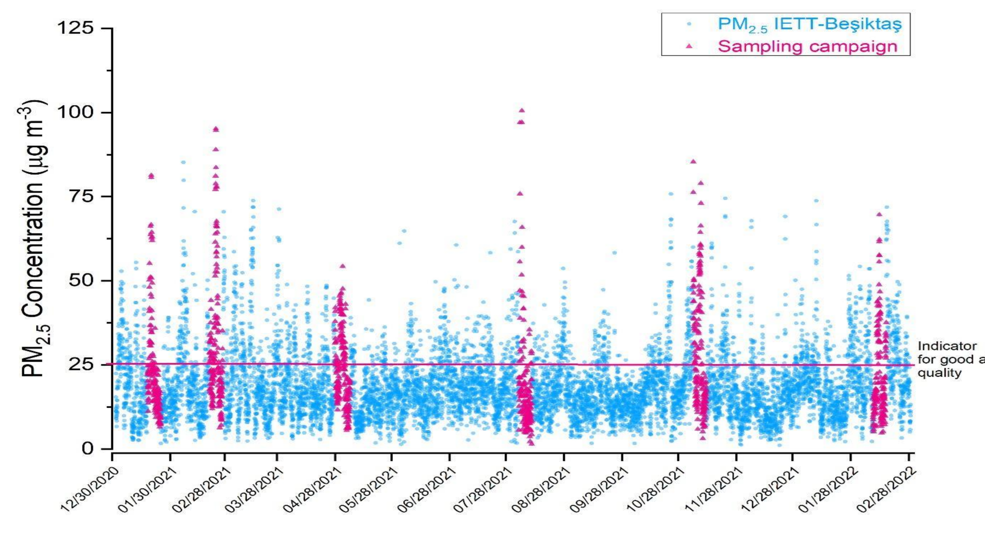

Figure 4. Hourly $PM_{2.5}$ concentrations in Besiktas_IETT, Istanbul. The red markers indicate high time resolved sampling for OC and EC analysis.

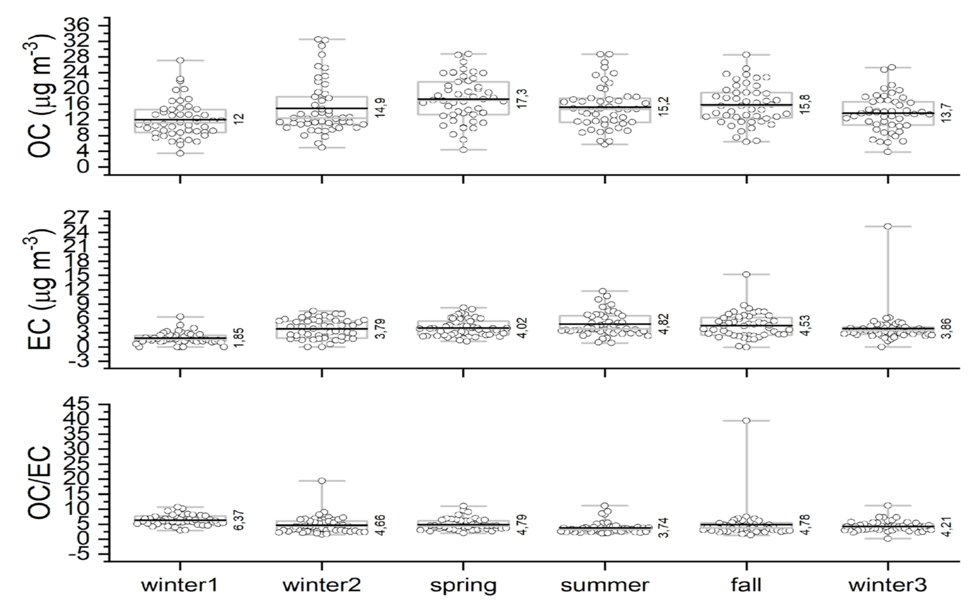

Figure 5. Seasonal variation of high time-resolved OC and EC. Average concentrations are indicated by a black horizontal line.

The OC values are higher in 2021 compared to 2017, however, the EC concentrations are higher in the 2017 data. The OC in 2017 is due to fuel combustion and in 2021 it shows an influence from coal and wood burning, residential heating in general. These differences can be credited to population increase, and Covid-19 lockdowns considering in these time periods the traffic was low, only the governmental and necessity work areas were open.

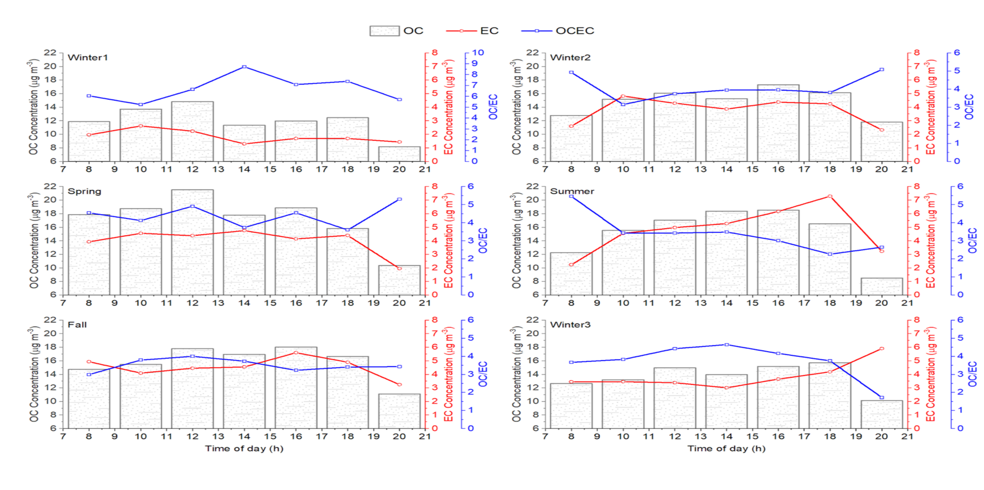

Figure 6. Diurnal variation of OC (bar), EC (red line), and OC/EC ratios (blue line) during various seasons.

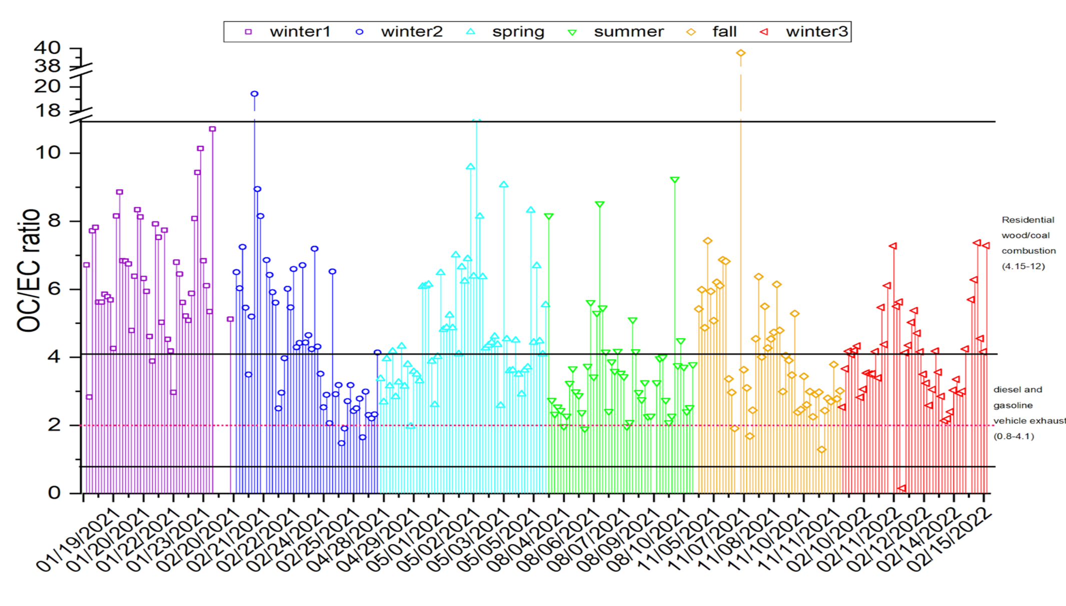

Figure 7. High time-resolved OC/EC ratios during various seasons and the possible sources.

IV. CONCLUSION AND DISCUSSION

In this project, high time resolution $PM_{2.5}$ samples were used to investigate the characteristics of $PM_{2.5}$, OC, and EC in an urban traffic region ,Beşiktaş Istanbul, as well as the impacts of meteorological and traffic on overall air quality.

For three weeks throughout the winter and one week each during the spring, summer, and fall, samples were taken at 2-hour intervals during the day and 12-hour intervals during the night.

Although the two highest for OC/EC values appear in winter and fall, there is no extreme difference between the values in general. However, the values are high and residential wood/coal combustion is observed in every season. When looking at the previous data, it can be said that the reason for the data to be higher in this project is due to the fact that the workplaces and factories that did not work during the lockdown period due to Covid-19 , started to work again in full capacity and also new businesses bloomed.

In addition to combustion activity on site of the sampling campaign ,some of the concentration are due to OC and EC that were transferred from surrounding cities, industrial sites, and shipping emissions at the N,NW respectively.

To reduce the air pollution and emissions in general the regulations should be revised and become stricter as it is. Most urgent and rapid way to manage these emissions are to use high quality fuel for both transportation and residential heating. The critical season for this is cold seasons due to bad mixing in the atmosphere.

V. ACKNOWLEDGMENTS

BAPKO (Bilimsel Araştırma Projeleri Birimi) at Marmara University and TUBITAK for travel grant. Turkish Government Traffic Agencies and Turkish Ministry of Environment and Urbanisation for providing traffic data and $PM_{2.5}$ data