

Supplementary Materials:

Low-Cost Air Quality Sensors: One-Year Field Comparative Measurement of different Gas Sensors and Particle Counters with Reference Monitors at Tušimice Observatory

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Supplementary tables

Table S1. The number of valid data (hourly average concentrations; shown in percentage) measured by pairs of different Cairclip sensors in particular months of testing period.

Sensor type	Sensor ID	N ¹	Valid data (%) in particular months										
			11/2017	12/2017	1/2018	2/2018	3/2018	4/2018	5/2018	6/2018	7/2018	8/2018	9/2018
Cairclip	1	7031	100.0	100.0	94.8	100.0	80.0	100.0	90.3	100.0	100.0	100.0	81.9
SO ₂	2	5383	26.1	3.0	25.8	57.0	79.2	100.0	90.1	100.0	100.0	100.0	81.9
Carclip	1	7031	100.0	100.0	94.8	100.0	80.0	100.0	90.3	100.0	100.0	100.0	81.9
NO ₂	2	7031	100.0	100.0	94.8	100.0	80.0	100.0	90.3	100.0	100.0	100.0	81.9
Cairclip	1	7031	100.0	100.0	94.8	100.0	80.0	100.0	90.3	100.0	100.0	100.0	81.9
O ₃	2	7031	100.0	100.0	94.8	100.0	80.0	100.0	90.3	100.0	100.0	100.0	81.9
Cairclip	1	7031	100.0	100.0	94.8	100.0	80.0	100.0	90.3	100.0	100.0	100.0	81.9
CO	2	7031	100.0	100.0	94.8	100.0	80.0	100.0	90.3	100.0	100.0	100.0	81.9

¹ N = total number of valid data (hourly average concentrations) for the whole testing period.

Table S2. Correlation matrix of gas concentrations (in ppb, CO in ppm) measured by different pairs of Cairclip Cairpol sensors (Cair1, Cair2) and of ambient air temperature (T in °C) and relative humidity (RH in %).¹

Sensor	SO ₂ Cair1	SO ₂ Cair2	NO ₂ Cair1	NO ₂ Cair2	O ₃ Cair1	O ₃ Cair2	CO Cair1	CO Cair2	T
SO ₂ Cair2	0.99								
NO ₂ Cair1	1.00	0.99							
NO ₂ Cair2	1.00	0.99	1.00						
O ₃ Cair1	1.00	0.98	1.00	1.00					
O ₃ Cair2	1.00	0.99	1.00	1.00	1.00				
CO Cair1	1.00	0.99	1.00	1.00	1.00	1.00			
CO Cair2	0.80	0.83	0.82	0.82	0.79	0.81	0.80		
T	0.80	0.86	0.82	0.82	0.79	0.80	0.80	0.79	
RH	-0.66	-0.65	-0.65	-0.65	-0.66	-0.66	-0.66	-0.50	-0.62

¹ Spearman correlation coefficients (r_s) are shown, all values were statistically significant at the level of $p < 0.05$. Correlation coefficients of different kind of gas sensors with air temperature and relative humidity are highlighted in bold. N = 5383.

Table S3. The number of valid data (hourly average concentrations; shown in percentage) measured by pairs of PMS7003 Plantower particle counters in particular months of testing period.

Sensor type	Sensor ID	N	Valid data (%) in particular months									
			3/2018	4/2018	5/2018	6/2018	7/2018	8/2018	9/2018	10/2018	11/2018	12/2018
PMS7003 PM₁	1	6736	99.4	99.3	90.3	99.6	99.5	99.1	81.9	94.9	92.1	78.4
	2	6852	99.8	99.7	90.5	99.7	99.9	99.5	82.8	96.1	92.2	89.9
PMS7003 PM_{2.5}	1	6840	99.5	99.6	90.5	99.7	99.9	99.1	82.6	96.2	92.2	89.1
	2	6712	99.4	98.9	90.5	99.2	99.2	98.0	81.1	94.6	92.2	78.1
PMS7003 PM₁₀	1	6919	100.0	100.0	90.5	100.0	100.0	100.0	83.1	98.5	92.2	94.9
	2	6922	99.7	100.0	90.5	100.0	100.0	100.0	83.1	98.5	92.2	95.4

¹ N = total number of valid data (hourly average concentrations) for the whole testing period.

Table S4. The number of valid data (hourly average concentrations; shown in percentage) measured by pairs of OPC-N2 Alphasense particle counters in particular months of testing period.

Sensor type	Sensor ID	N	Valid data (%) in particular months				
			9/2018	10/2018	11/2018	12/2018	1/2019
OPC-N2 PM₁	1	2288	38.6	75.0	100.0	100.0	100.0
	2	2288	38.6	75.0	100.0	100.0	100.0
OPC-N2 PM_{2.5}	1	2288	38.6	75.0	100.0	100.0	100.0
	2	2072	18.2	53.6	100.0	100.0	100.0
OPC-N2 PM₁₀	1	2072	18.2	53.6	100.0	100.0	100.0
	2	2071	17.9	53.6	100.0	100.0	100.0

¹ N = total number of valid data (hourly average concentrations) for the whole testing period.

Table S5. Correlation matrix of PM mass concentrations (in $\mu\text{g}/\text{m}^3$) measured by two PMS7003 Plantower particle counters (Plant1, Plant2) and of ambient air temperature (T in $^{\circ}\text{C}$) and relative humidity (RH in %).¹

Sensor	PM ₁ Plant1	PM ₁ Plant2	PM _{2.5} Plant1	PM _{2.5} Plant2	PM ₁₀ Plant1	PM ₁₀ Plant2	T
PM₁ Plant2	0.95						
PM_{2.5} Plant1	1.00	0.95					
PM_{2.5} Plant2	0.95	1.00	0.96				
PM₁₀ Plant1	0.99	0.95	1.00	0.96			
PM₁₀ Plant2	0.94	0.99	0.95	0.99	0.96		
T	-0.27	-0.24	-0.31	-0.28	-0.32	-0.29	
RH	0.48	0.46	0.51	0.49	0.52	0.50	-0.69

¹ Spearman correlation coefficients (r_s) are shown, all values were statistically significant at the level of $p < 0.05$. Correlation coefficients of different kind of gas sensors with air temperature and relative humidity are highlighted in bold. N = 6589.

Table S6. Correlation matrix of PM mass concentrations (in $\mu\text{g}/\text{m}^3$) measured by two OPC-N2 Alphasense particle counters (Alpha1, Alpha2) and of ambient air temperature (TMP in $^{\circ}\text{C}$) and relative humidity (RH in %).¹

Sensor	PM ₁ Alpha1	PM ₁ Alpha2	PM _{2.5} Alpha1	PM _{2.5} Alpha2	PM ₁₀ Alpha1	PM ₁₀ Alpha2	T
PM ₁ Alpha2	0.99						
PM _{2.5} Alpha1	0.99	0.99					
PM _{2.5} Alpha2	0.99	0.99	0.99				
PM ₁₀ Alpha1	0.98	0.98	1.00	0.99			
PM ₁₀ Alpha2	0.98	0.98	0.99	0.99	0.99		
T	-0.17	-0.22	-0.17	-0.22	-0.16	-0.21	
RH	0.58	0.59	0.58	0.60	0.57	0.59	-0.36

¹ Spearman correlation coefficients (r_s) are shown, all values were statistically significant at the level of $p < 0.05$. Correlation coefficients of different kind of gas sensors with air temperature and relative humidity are highlighted in bold. N = 2028.

1. Supplementary figures

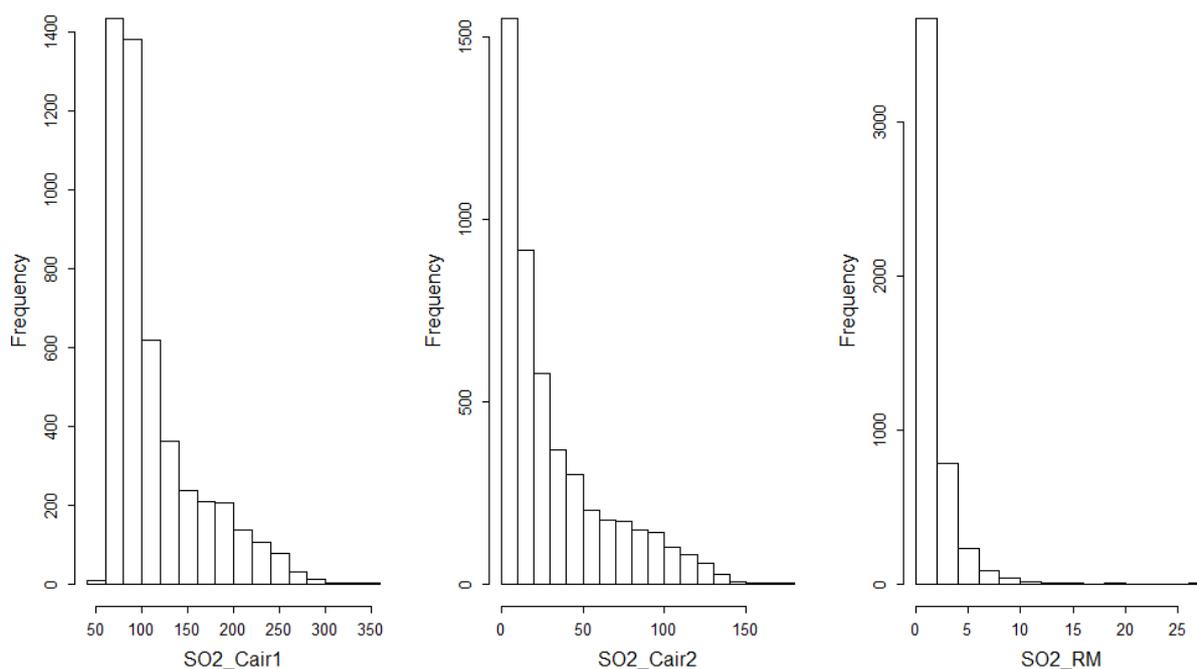


Figure S1. Histograms of SO₂ concentrations (ppb) measured by Cairclip sensors pair (Cair1, Cair2) and by corresponding reference monitor (RM).

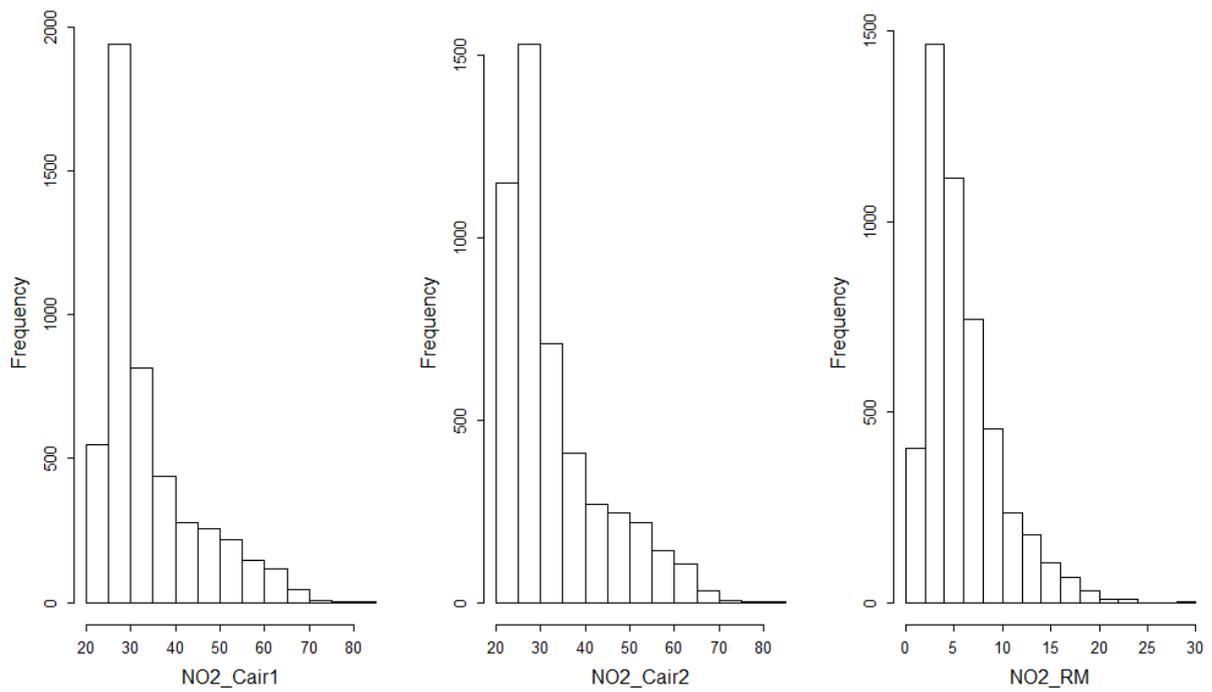


Figure S2. Histograms of NO₂ concentrations (ppb) measured by Cairclip sensors pair (Cair1, Cair2) and by corresponding reference monitor (RM).

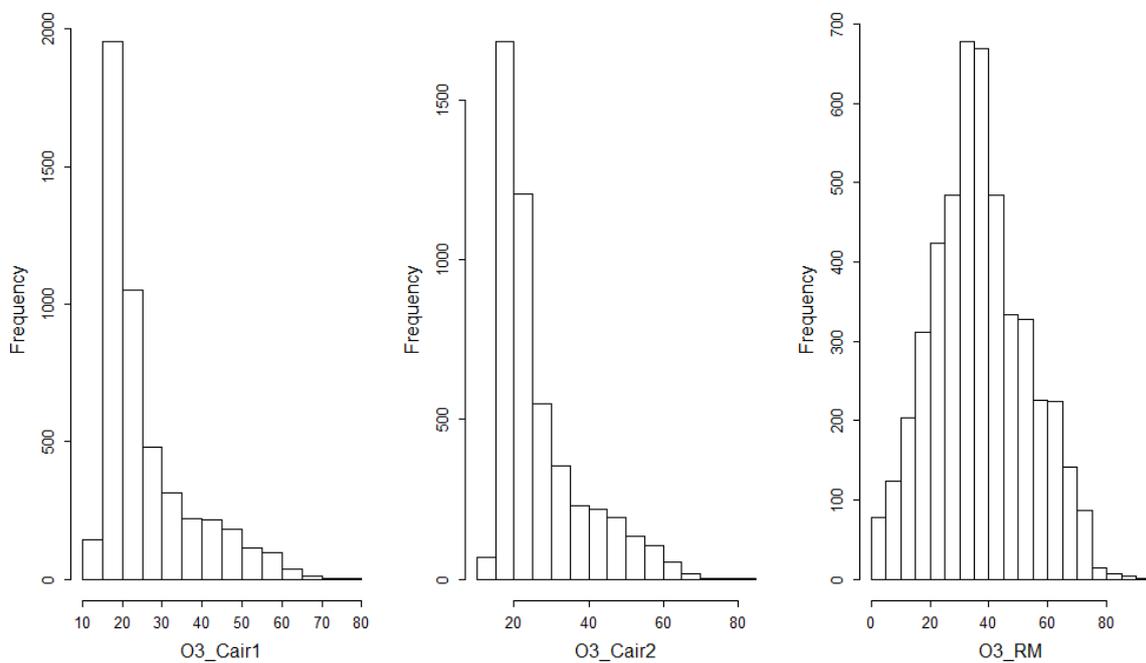


Figure S3. Histograms of O₃ concentrations (ppb) measured by Cairclip sensors pair (Cair1, Cair2) and by corresponding reference monitor (RM).

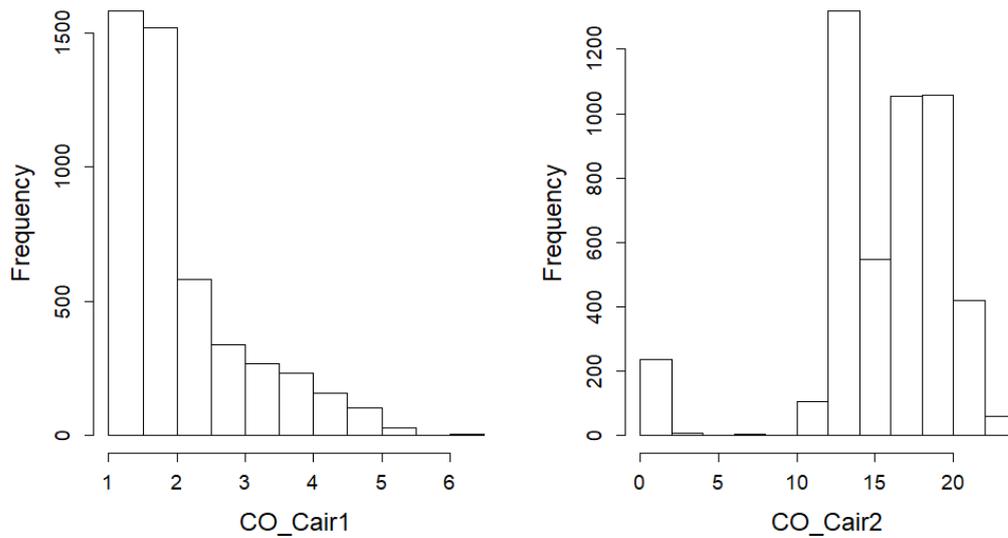


Figure S4. Histograms of CO concentrations (ppm) measured by Cairclip sensors pair (Cair1, Cair2). Corresponding reference monitor is not available at this measuring station.

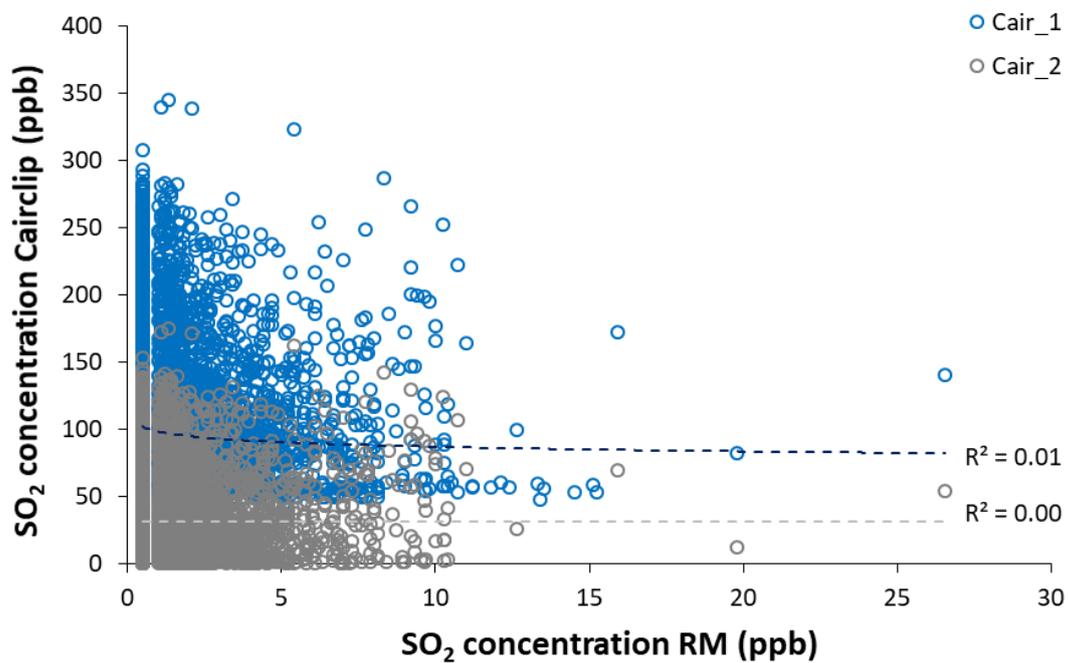


Figure S5. The lack of relationship between SO₂ concentrations measured by Cairclip sensors and by RM. Coefficient of determination (R^2) was estimated from polynomial best-fit regression line (degree = 2).

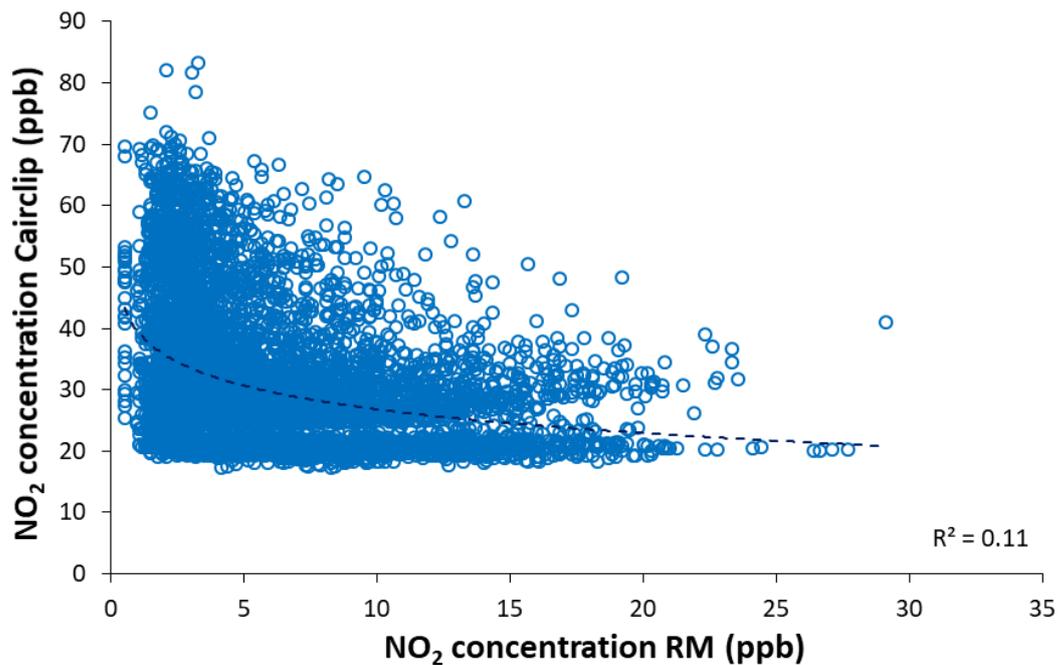


Figure S6. The negative relationship between NO₂ concentrations measured by Cairclip sensors and by RM. Coefficient of determination (R^2) was estimated from logarithmic best-fit regression line.

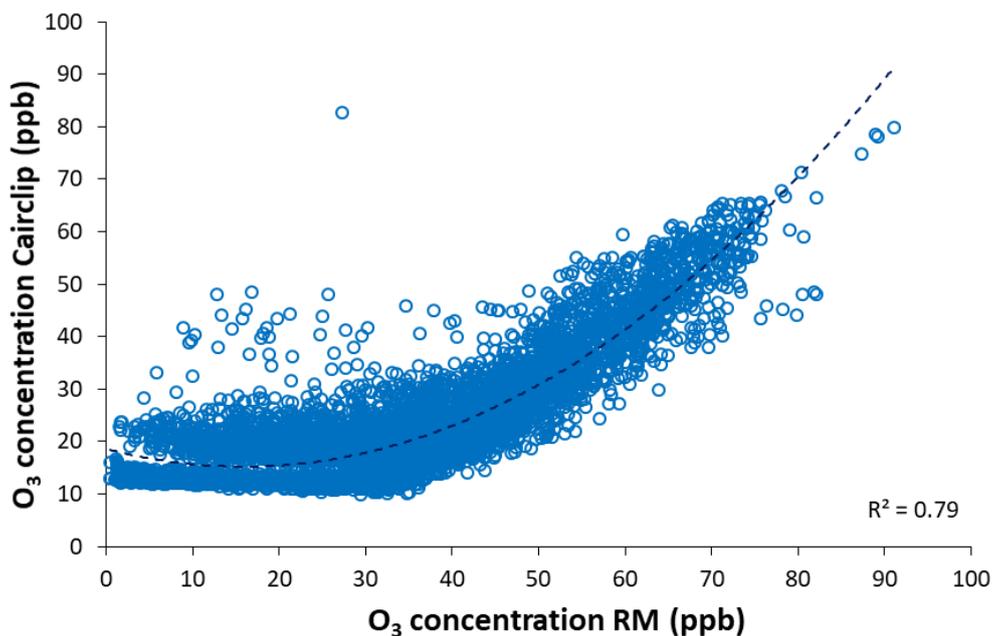


Figure S7. The relationship between O₃ concentrations measured by Cairclip sensors and by RM. Coefficient of determination (R^2) was estimated from polynomial best-fit regression line (degree = 2).

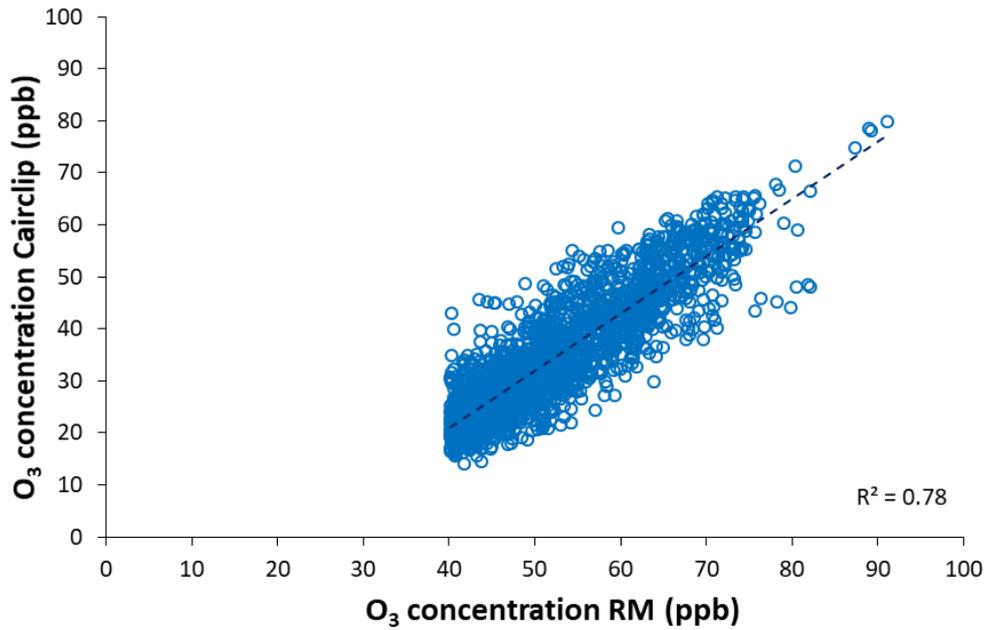


Figure S8. The relationship between O₃ concentrations measured by Cairclip sensors and by RM, while the O₃ concentrations measured by RM were limited to values higher than 40 ppb. Coefficient of determination (R^2) was estimated from linear best-fit regression line.

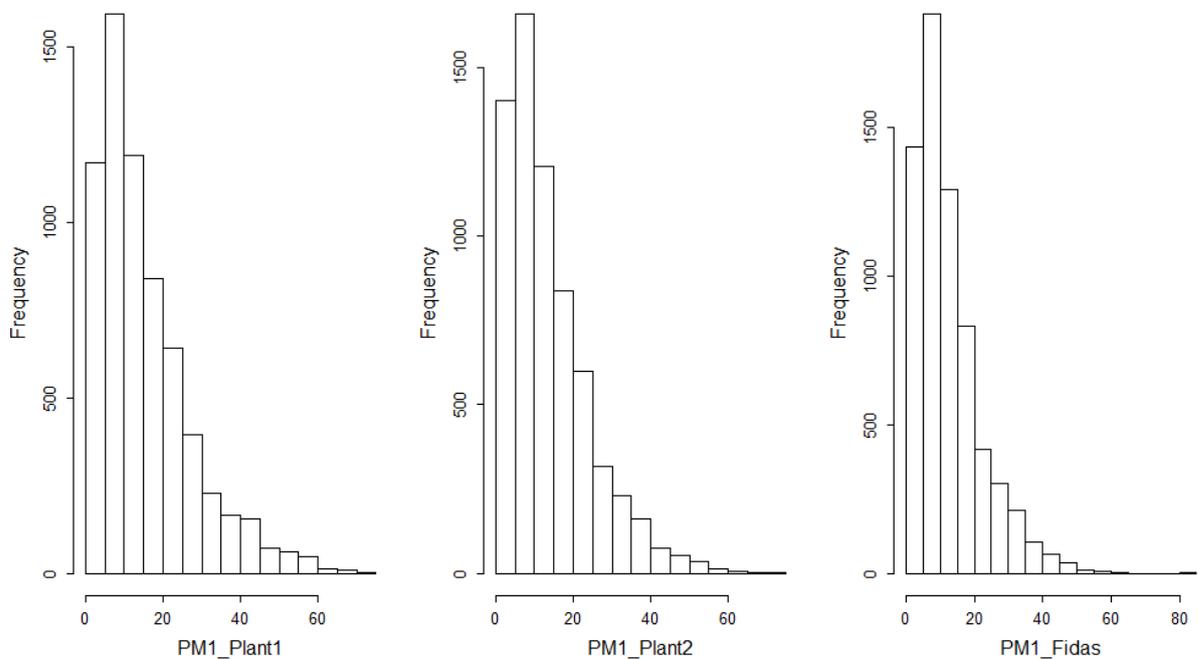


Figure S9. Histograms of PM₁ concentrations (µg/m³) measured by PMS7003 Plantower particle counters (Plant1, Plant2) and by equivalent optical Fidas200 monitor (Fidas).

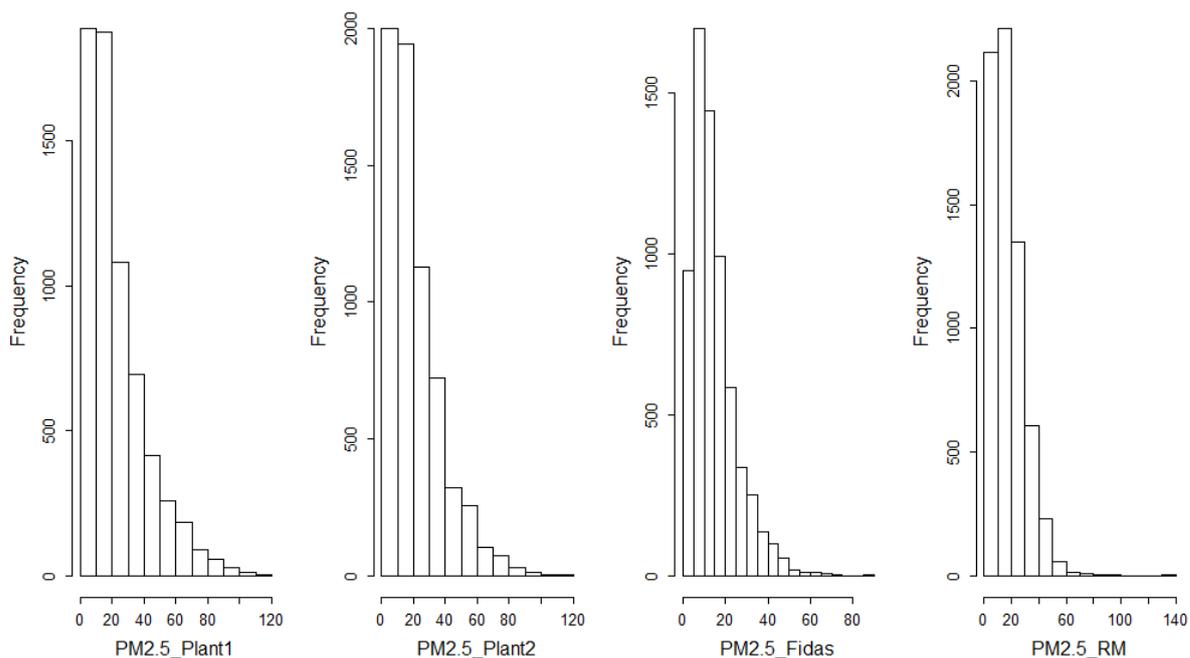


Figure S10. Histograms of PM_{2.5} concentrations (µg/m³) measured by PMS7003 Plantower particle counters (Plant1, Plant2), by equivalent optical Fidas200 monitor (Fidas) and by radiometric RM (RM).

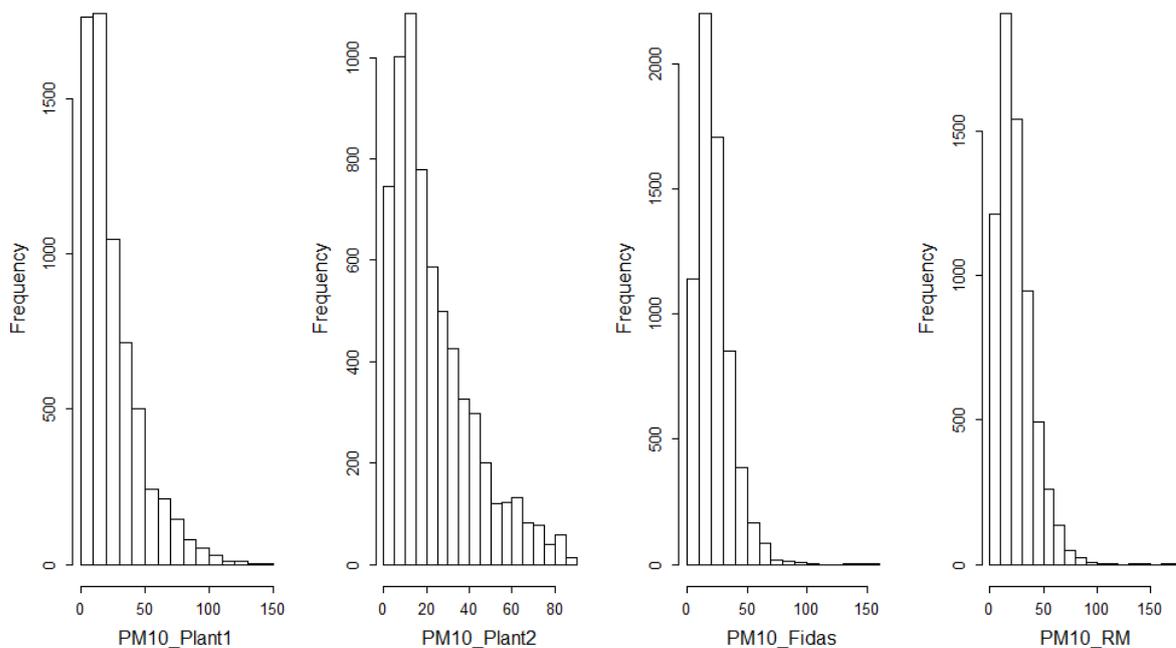


Figure S11. Histograms of PM₁₀ concentrations ($\mu\text{g}/\text{m}^3$) measured by PMS7003 Plantower particle counters (Plant1, Plant2), by equivalent optical Fidas200 monitor (Fidas) and by radiometric RM (RM).

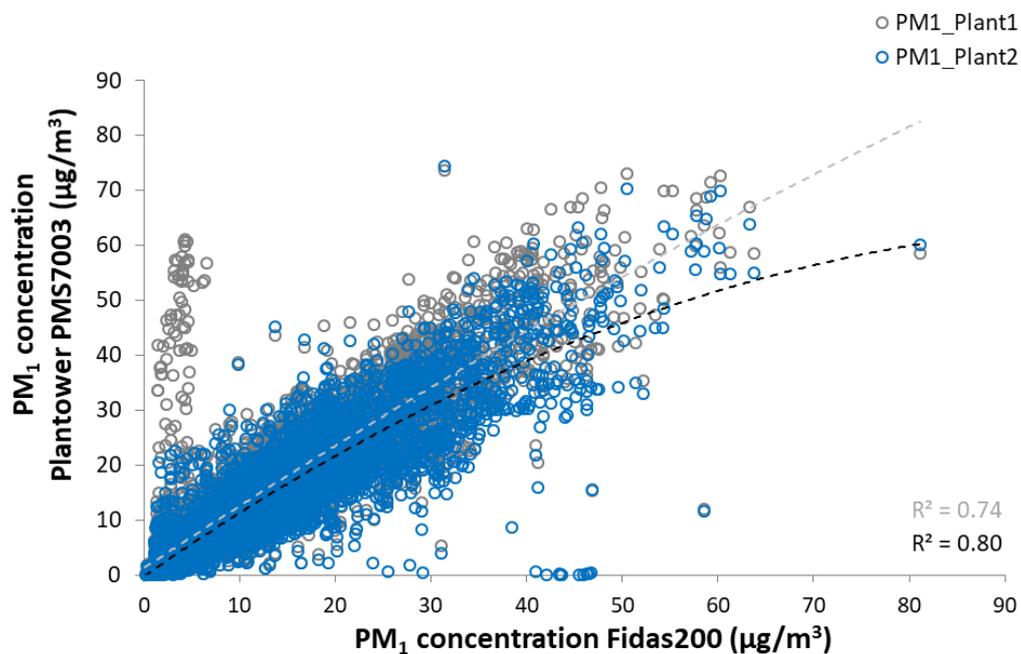


Figure S12. The relationship between PM₁ concentrations ($\mu\text{g}/\text{m}^3$) measured by Plantower PMS7003 particle counters (Plant1 in grey, Plant2 in blue) and by equivalent optical Fidas200 monitor. Coefficients of determination (R^2) were estimated from linear best-fit regression lines.

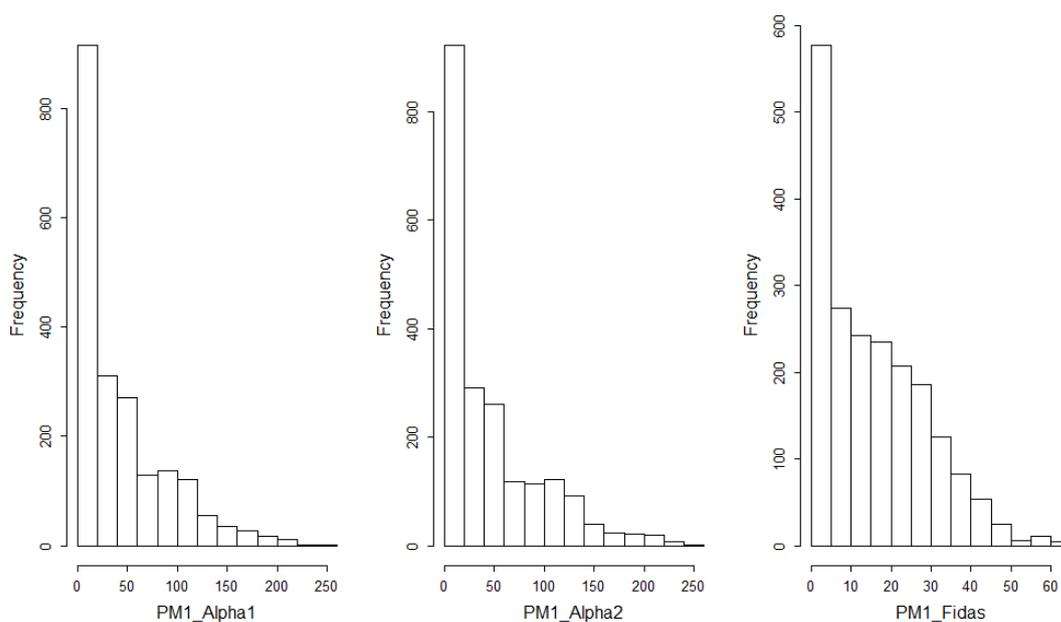


Figure S13. Histograms of PM₁ concentrations ($\mu\text{g}/\text{m}^3$) measured by OPC-N2 Alphasense particle counters (Alpha1, Alpha2) and by equivalent optical Fidas200 monitor (Fidas).

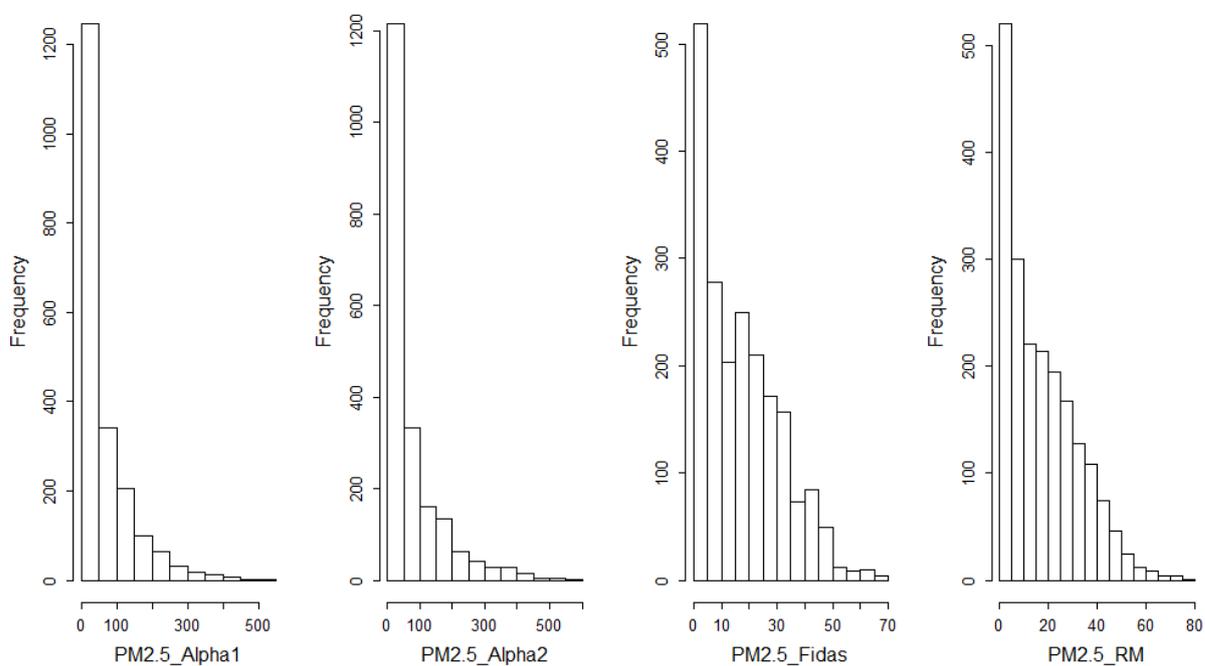


Figure S14. Histograms of PM_{2.5} concentrations ($\mu\text{g}/\text{m}^3$) measured by OPC-N2 Alphasense particle counters (Alpha1, Alpha2), by equivalent optical Fidas200 monitor (Fidas) and by radiometric RM (RM).

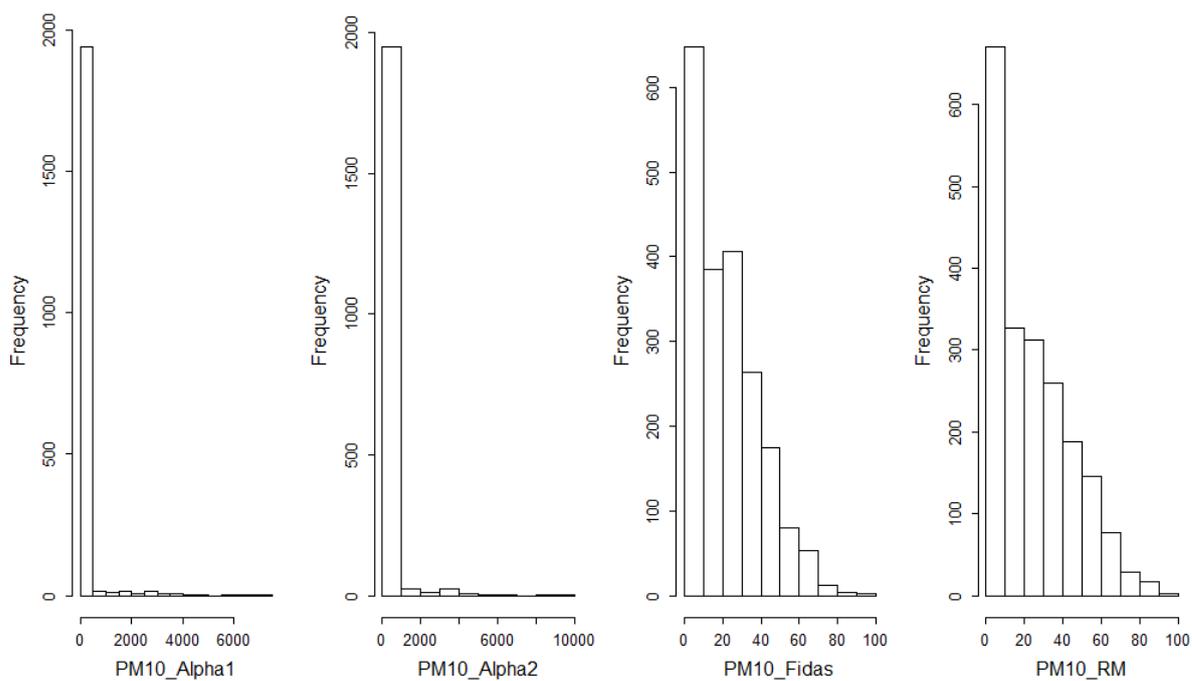


Figure S15. Histograms of PM₁₀ concentrations ($\mu\text{g}/\text{m}^3$) measured by OPC-N2 Alphasense particle counters (Alpha1, Alpha2), by equivalent optical Fidas200 monitor (Fidas) and by radiometric RM (RM).

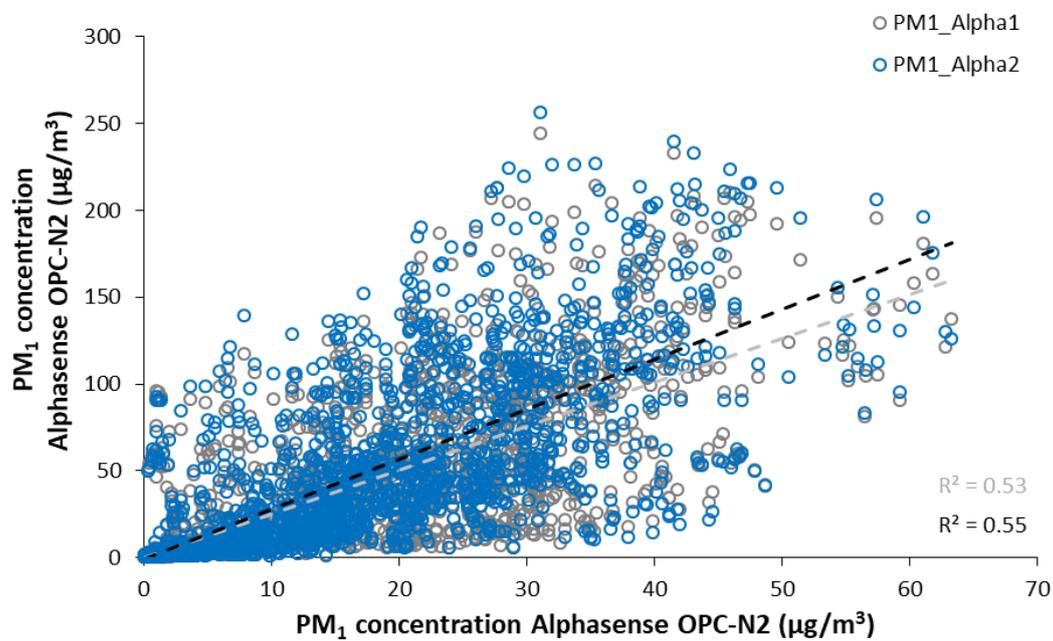


Figure S16. The relationship between PM₁ concentrations ($\mu\text{g}/\text{m}^3$) measured by Alphasense OPC-N2 particle counters (Alpha1 in grey, Alpha2 in blue) and by equivalent optical Fidas200 monitor. Coefficients of determination (R^2) were estimated from linear best-fit regression lines.

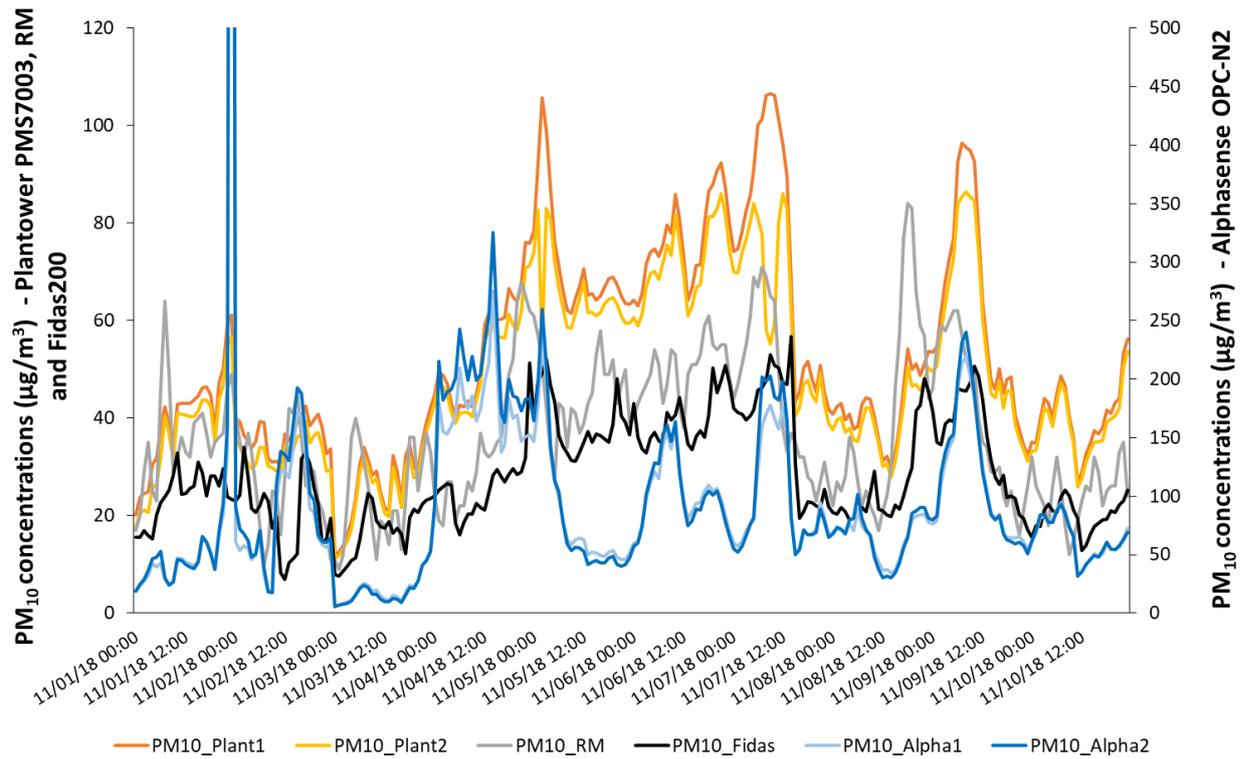


Figure S17. The course of hourly PM₁₀ concentrations (µg/m³) measured by Plantower and Alphasense particle counters in comparison with RM and Fidas200 monitor during the selected part of testing period (from November 1 until November 10, 2018). Mass concentrations measured by Alphasense sensors are displayed on the secondary y axis (on the right). Given the presence of extreme outliers the scale of the axis was intentionally limited (only up to 500 µg/m³).