Electronic Supplementary Information

INFLUENCE OF COMBINED DUST REDUCING CARPET AND COMPACT AIR FILTRATION UNIT ON THE INDOOR AIR QUALITY OF A CLASSROOM

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INTRODUCTION

The first section 'General information on conditions during the observation period' contains information such as the dates of the study period, the general meteorological conditions and information on changes in the general outdoor air quality during the study period.

The technical specifications of the interventions are provided in Tables S1 and S2. The outdoor temperature, humidity and measured air quality parameters are presented in Table S3. The indoor temperature, humidity and measured air quality parameters over the entire study period are provided in Table S4 for classroom A and in Table S5 for classroom B. The changes of the IAQ parameters from the baseline to the intervention setting are presented in Table S6. An overview of the I/O ratios for all studied conditions is presented in Table S7. Figure S1 show some photos of the school building and Figure S2 shows the interior of the classroom at the time the interventions were installed. The outdoor concentrations of PM-10 and PM-2.5 at the school and the PM-10 concentration at a nearby air monitoring station over the entire study period are presented in Figure S3.

GENERAL INFORMATION ON CONDITIONS DURING THE OBSERVATION PERIOD

The measurements started on Monday November 1st 2011 and were finalized on Friday December 2nd 2011. The outdoor temperature (Table S3) was exceptionally high for November in the Netherlands with an average air temperature ranging from 9.6 to 19.4°C. It was the third sunniest month since 1908 with 95 sun hours compared to an average of 63 and there was only 9 ml of precipitation compared to 82 on average since 1906. The average relative humidity ranged from 55.5 to 68.0%. The wind direction was atypical showing more South to East wind direction than usual, resulting in more stable or stagnant atmospheric conditions than usual and on some days fog occurred (KNMI, 2012). The indoor air temperature was approximately 18°C during the weekend and around 22°C during teaching hours and comparable in the two classrooms (see Table S4 for classroom A and Table S5 for classroom B). Only during the first weekend the average temperature in classroom A was somewhat higher than in classroom B (19.3°C vs. 18.3°C). The average relative humidity varied between 35 and 60% and was similar in both classrooms (Tables S4 and S5). During the weekend the concentration of CO_2 was 400-500 ppm, corresponding to outdoor values. During the lessons the CO_2 concentrations reached hour-average values of 1,500 to 2,100 ppm in both classrooms. The general outdoor air quality was rather poor, due to the stagnant atmospheric conditions. This resulted in a time-weighted average of PM-10 of 42 $\mu g/m^3$ and a PM-2.5 value 34 $\mu g/m^3$ over the entire study period, based on local measurements at the school location. For PM-2.5 and PM-10 the outdoor concentrations went up to levels above 100 $\mu g/m^3$ during episodes of high PM air pollution on November 7-8 and a high peak of PM-10 on November 23 (Figure S3). The pattern of PM-10 at the study location agreed well with the general background PM-10 levels over the study period measured at other air monitoring locations in The Netherlands.

REFERENCE

KNMI (2012) *Maandoverzicht van het weer in Nederland. november 2011*. De Bilt, Koninklijk Nederlands Meteorologisch Insituut. http://www.knmi.nl/klimatologie/mow/pdf/mow_201111.pdf

Table S1: Technical data and product claims for the dust reducing carpet.

Manufacturer	Desso, Waalwijk, The Netherlands
Type	AirMaster®
Description	Carpet tiles
Dimensions	50 x 50 cm
Technical description	The carpet consists of thin yarns capturing and retaining the fine dust (DESSO Airfilters™) and thicker yarns capturing and retaining the coarser fine dust (DESSO DustCollectors™) For more technical information see: http://www.desso-airmaster.com/)
Maintenance	Vacuum cleaning in the direction of the pile, at least twice a week, using a vacuum cleaner with a HEPA filter
Results of laboratory testing	The concentration of PM-10 was fourfold lower compared to a standard structured loop pile carpet and eightfold lower compared to a hard polyvinyl floor[a]

[a] The authors were given access to the original reports.

Table S2: Technical data and product claims for the air filtration unit.

Manufacturer	Philips, Drachten, The Netherlands
Type	AC4091
Technology used	Filtration and adsorption
Filter type	Pre-filter and formaldehyde filter (type AC4187)
Effective area	up to 70 m^2
Air filtration capacity	Setting 1: (AUTO) Setting 2: (SILENT): 150 m^3/h Setting 3: 180 m^3/h Setting 4: 270 m^3/h Setting 5 (TURBO): 390 m^3/h
Clean air delivery rate (CADR)*	340 m^3/h
Ozon emission	Negligible
Noise level	37 (SILENT) – 58 dB (TURBO).
Wattage	51 W
Dimensions (W x D x H)	45.5 x 29.5 x 68.5 cm
Weight	12 kg
Maintenance	If the pre-filter is soiled (indicated by the flashing sensor) the filter can be removed and cleaned using tap water followed by air drying. For the use in homes it is recommended to clean the pre-filter once every two weeks
Change of filters	Once every three years for the use in homes
Reduction particulate matter	98.1 % dust/pollen (0.3 µm)[a]
Reduction of VOC	98.1 % for total VOC[a] 97.5 % for benzene[a]
Reduction of formaldehyde	99.1 % for formaldehyde when using filter AC4187[a]
Reduction of microorganisms	>99.9 % of for bacteria (*Staphylococcus alba*)

[a] These results were obtained at the Guandong Detection Centre of Microbiology.

Tabel S3: Temperature, relative humidity and other indicators of outdoor air quality.

Indicator	**Week 1**	**Weekend 2**	**Week 2**	**Weekend 3**	**Week 3**	**Weekend 4**	**Week 4**	**Weekend 5**	**Week 5**
Temperature (°C)	19.4	16.0	13.7	-	-	9.6	10.0	13.0	12.1
	(17.1-20.7)	(14.5-20.6)	(13.2-14.4)			(8.0-15.4)	(9.1-11.6)	(11.4-14.1)	(11.0-12.9)
Relative humidity (%)	55.5	61.81	62.4	-	-	67.7	66.9	69.0	61.8
	(51.9-59.5)	(47.5-65.2)	(60.0-68.1)			(56.3-71.8)	(63.6-74.2)	(63.2-70.1)	(58.9-66.4)
CO_2 (ppm)	375	412	423	-	-	470	476	382	409
	(361-401)	(397-417)	(416-438)			(457-484)	(405-533)	(381-390)	(402-418)
CO_2 (98-percentile)	410	436	467	-	-	536	609	396	449
PM-2.5 ($\mu g/m^3$)	19	30	60	47	38	33	44	21	18
	(12-21)	(17-70)	(38-93)	(37-51)	(32-48)	(31-40)	(39-52)	(19-24)	(11-27)
PM-10 ($\mu g/m^3$)	22	36	67	44	50	40	57	37	28
	(14-27)	(21-65)	(39-105)	(39-53)	(42-58)	(33-48)	(45-67)	(31-40)	(25-32)
VOC[b.e] ($\mu g/m^3$)	<1.0	<1.0	<1.0	<1.0	41.05	68.10	<1.0	<1.0	148.70
Formaldehyde[b.e] ($\mu g/m^3$)	<1.0	1.24	<1.0	1.23[d]	<1.0	<1.0	<1.0	<1.0	0.74[d]
NO_2[b.e] ($\mu g/m^3$)	52.3	22.4	27.0	28.67	23.0	29.1	38.9	34.8	35.3

[a] Mean concentration of PM based on only one filter (sampling of two intervals of 7 h); [b] Arithmetic mean of observations in duplicate; [c] Arithmetic mean with 25th and 75th percentile values; [d] Single observation; [e] Based on one continuous measurement during the entire week; * Intervention period; - No data available; < lod = below the limit of determination.

Table S4: Temperature and relative humidity and indicators of air quality in classroom A (Means and 0.25 and 0.75 percentiles). The columns containing the data related to interventions (Weekend 2 and week 2).

Parameter	Week 1	Weekend 2*	Week 2*	Weekend 3	Week 3	Weekend 4	Week 4	Weekend 5	Week 5
Temperature (°C)	23.6 (22.4-24.4)	19.3 (18.2-20.5)	22.8 (21.78-23.9)	17.7 (17.3-17.9)	23.4 (22.1-24.5)	17.8 (17.3-18.2)	22.70 (21.71-23.73)	17.9 (17.8-18.0)	22.8 (21.4-23.5)
Relative humidity (%)	53.1 (49-56)	51.3 (50.2-51.6)	46.1 (42.7-49.4)	39.3 (37.6-40.9)	37.50 (32.6-43.9)	41.5 (38.8-42.9)	46.15 (41.42-50.01)	46.1 (44.3-46.9)	45.89 (43.2-49.7)
CO_2 (ppm)	1509 (1166-2108)	503 (494-528)	1811 (1157-2226)	478 (441-551)	2066 (1700-2674)	532 (515-571)	2115 (1679-2534)	442 (437-454)	2068 (1256-2605)
CO_2 (98 percentile)	2801	552	2859	565	3108	579	3324	458	3005
PM-1.0 (spec) (µg m^{-3})	14.03 (10.43-19.91)	3.01 (1.94-5.81)	17.65 (12.60-29.80)	25.45 (24.00-26.79)	22.43 (17.27-28.15)	12.35 (11.97-13.19)	21.36 (17.33-31.03)	6.68 (4.58-8.83)	8.92 (4.89-13.29)
PM-2.5 (spec) (µg m^{-3})	28.66 (19.44-38.56)	3.16 (2.06-5.97)	27.07 (17.75-40.95)	25.84 (24.40-27.25)	34.03 (28.20-40.44)	12.52 (12.10-13.57)	39.53 (28.78-46.43)	8.26 (6.60-10.06)	24.73 (14.20-31.40)
PM-10 (spec) (µg m^{-3})	131.64 (82.67-192.26)	3.18 (2.06-5.99)	103.36 (56.54-148.21)	25.98 (24.52-27.36)	110.95 (67.87-153.7)	12.56 (12.13-13.61)	148.67 (91.55-203.70)	8.61 (7.01-10.37)	133.29 (78.03-178.3)
PM-2.5 (grav)[b] (µg m^{-3})	28.5 (19.8-37.1)	n.d[a*]	24.3 (20.0-31.9)	19.1[a]	27.8 (26.0-30.6)	11.6[a]	35.9 (25.0-42.8)	6.7[a]	24.0 (22.3-25.4)
PM-10 (grav)[b] (µg m^{-3})	70.9 (66.6-75.3)[c]	3.3[a]	83.4 (72.8-84.7)	17.5[a]	88.4 (82.6-86.7)	9.5[a]	126.3 (114.7-126.2)	9.8[a]	124.4 (108.0-136.1)
BS (PM-10) (10^{-5} m^{-1})	2.0 (1.9-2.1)[c]	0.5[a]	2.2 (2.2-2.8)	2.7[a]	3.2 (2.9-3.5)	2.5[a]	4.9 (2.4-6.5)	0.5[a]	1.9 (1.5-2.1)
BS (PM-2.5) (10^{-5} m^{-1})	1.7 (1.4-2.1)	0.4[a]	2.0 (2.0-2.3)	2.4[a]	2.9 (2.9-3.2)	2.8[a]	4.8 (2.0-6.4)	1.0[a]	1.6 (1.3-1.5)
VOS[b,e] (µg m^{-3})	63.55	<1.0	52.45	<1.0	89.20	<1.0	183.85	<1.0	106.30
Formaldehyde[b,e] (µg m^{-3})	23.1	17.17	22.48	15.7	20.23	14.83	25.65	12.89	22.01
NO_2[b,e] (µg m^{-3})	61.0	-	6.1	12.4	13.4	9.1	19.0	11.2	27.8

[a] Mean concentration of PM based on only one filter (sampling of two intervals of 7 h); [b] Arithmetic mean of observations in duplicate; [c] Arithmetic mean with 25th and 75th percentile values; [d] Single observation; [e] Based on one continuous measurement during the entire week; * Intervention period; - No data available; < lod = below the limit of determination.

Table S5: Temperature and relative humidity and indicators of air quality in classroom B (Means and 0.25 en 0.75 percentiles). The columns containing the data related to interventions (Weekend 4 and week 4).

Parameter	Week 1	Weekend 2	Week 2	Weekend 3	Week 3	Weekend 4*	Week 4*	Weekend 5	Week 5
Temperature (°C)	23.4 (22.5-23.9)	18.3 (17.0-19.4)	22.4 (21.6-23.1)	17.1 (16.9-17.5)	22.1 (21.3-22.7)	17.1 (16.5-17.4)	21.7 (21.0-22.6)	17.8 (17.6-17.9)	22.3 (20.8-23.0)
Relative humidity (%)	52.8 (51.5-56.8)	54.6 (53.4-56.6)	47.5 (44.7-51.4)	41.8 (40.9-42.5)	40.8 (36.0-46.2)	43.6 (41.1-45.3)	46.5 (43.3-48.0)	46.8 (45.6-48.5)	45.4 (43.0-48.9)
CO_2 (ppm)	1472 (1035-1857)	435 (425-464)	1765 (1093-2087)	457 (445-506)	2044 (1522-2271)	507 (487-552)	1747 (1155-2500)	410 (403-424)	1639 (1095-2387)
CO_2 (98th percentile)	2509	489	2709	509	2724	561	3177	426	3116
PM-1.0 (spec) (µg m^{-3})	13.89 (11.94-20.48)	14.87 (9.50-26.84)	30.89 (20.76-52.31)	25.09 (23.25-26.16)	22.13 (18.12-28.34)	4.88 (4.56-5.39)	13.62 (8.83-16.02)	6.12 (4.18-8.37)	8.50 (4.90-13.05)
PM-2.5 (spec) (µg m^{-3})	31.77 (21.05-43.10)	15.45 (10.06-27.61)	46.65 (30.13-67.38)	25.48 (23.77-26.48)	30.93 (26.32-41.45)	4.95 (4.70-5.45)	22.61 (12.99-28.19)	7.39 (5.51-9.40)	20.94 (13.00-31.19)
PM-10 (spec) (µg m^{-3})	179.89 (113.5-259.9)	15.71 (10.27-27.88)	149.53 (83.51-189.81)	25.55 (23.90-26.51)	106.78 (78.26-141.00)	4.96 (4.72-5.45)	96.63 (40.58-144.89)	7.75 (5.75-9.63)	114.47 (50.75-193.60)
PM-2.5 (grav)[b] (µg m^{-3})	29.5 (21.8-37.3)	<3.0	38.9 (29.5-54.0)	19.2[a]	26.4 (25.4-28.8)	<3.0[a]	20.3 (15.3-21.6)	n.d[a]	22.3 (21.1-24.6)
PM-10 (grav)[b] (µg m^{-3})	114.7 (112.5-116.9)[c]	<3.0	124.8 (126.3-136.5)	19.8[a]	113.3 (100.9-121.4)	<3.0[a]	99.3 (85.3-122.6)	n.d[a]	121.8 (123.9-137.9)
BS (PM-10) (10^{-5} m^{-1})	2.3 (2.0-2.6)[c]	<0.5[a]	3.2 (3.2-4.2)	2.6[a]	3.4 (3.2-3.6)	1.1[a]	2.9 (1.9-3.3)	0.6[a]	2.2 (1.8-2.2)
BS (PM-2.5) (10^{-5} m^{-1})	1.4 (1.0-2.0)	<0.5[a]	3.0 (2.9-3.3)	2.7[a]	2.8 (2.7-3.2)	1.0[a]	2.3 (1.2-2.2)	0.7[a]	1.4 (1.0-1.3)
VOC[b,e] (µg m^{-3})	67.00	12.00	32.60	< lod	148.30	5.70	169.90	5.70	197.90
Formaldehyde[b,e] (µg m^{-3})	44.35	22.13	23.76	16.91	18.28	14.56	24.34	27.89	27.43
NO_2[b,e] (µg m^{-3})	-	10.4	3.48	11.3	9.36	12.51	-	6.84	18.53

[a] Mean concentration of PM based on only one filter (sampling of two intervals of 7 h); [b] Arithmetic mean of observations in duplicate; [c] Arithmetic mean with 25th and 75th percentile values; [d] Single observation; [e e] Concentrations five to tenfold lower than the actual outdoor levels at that time point; [*] Intervention period; - No data available; < lod = below the limit of determination.

Table S6: Relative change for non-intervention and intervention weekends and weeks.

	Weekend					Week				
	No intervention (%)		Intervention (%)		p-value	No intervention (%)		Intervention (%)		p-value
IAQ parameters	N	AM ± SD	N	AM ± SD		N	AM ± SD	N	AM ± SD	
PM-1.0 (spec)	2	-4.9 ± 3.5	2	-70.1 ± 9.6	0.059	3	-2.35 ± 1.67	2	-40.0 ± 2.9	0.001
PM-2.5 (spec)	2	-6.0 ± 4.6	2	-70.0 ± 9.5	0.066	3	-11.4 ± 2.78	2	-41.8 ± 1.1	0.002
PM-10 (spec)	2	-5.8 ± 4.2	2	-70.1 ± 9.6	0.064	3	-14.9 ± 9.43	2	-32.9 ± 2.1	0.144
PM-2.5 (grav)	1	0.52[a b]	1	-87.1[a]	-	3	-2.81 ± 2.10	2	-40.5 ± 3.0	0.001
PM-10 (grav)	2	11.6 [b]	2	-84.5 ± 0.32	-	3	-20.1 ± 15.7	2	-27.3 ± 5.9	0.637
BS (PM-10)	2	8.15 ± 11.9[b]	2	-65.5 ± 9.5	0.038	3	-10.9 ± 3.52	2	-36.0 ± 4.8	0.014
BS (PM-2.5)	2	-9.44 ± 20.6	2	-51.0 ± 13.4	0.093	3	-11.2 ± 5.82	2	-42.71 ± 9.4	0.036
VOC	2	-94.6 ± 4.56	2	-99.4 ± 0.23	0.250	3	26.7 ± 28.7[b]	2	-34.2 ± 20.5	0.198
Formaldehyde	2	-23.0 ± 30.7	2	-12.1 ± 10.3	0.441	3	-14.7 ± 5.06	2	-5.25 ± 0.14	0.194
Nitrogen dioxide	2	-24.1 ±1 5.0	2	19.0 ± 19.0[b]	0.216	3	46.4 ± 3.59[b]	1	-75.6[a]	-

[a] The result of one week or weekend was not available due to technical difficulties; [b] Negative values represent an increase in the IAQ parameter.

Table S7: Average ± sd indoor/outdoor (I/O) ratios for non-intervention and intervention weekends and weeks.

IAQ parameters	Weekend					Week				
	No intervention		Intervention			No intervention		Intervention		
	Classroom A (N=3)	Classroom B (N=3)	Both classrooms (N=2)	Change (%)	p-value[a]	Classroom A (N=4)	Classroom B (N=4)	Both classrooms (N=2)	Change (%)	p-value[a]
PM-2.5 (spec)	0.44 ± 0.08	0.48 ± 0.06	0.13 ± 0.02	-72	0.0003	1.2 ± 0.28	1.2 ± 0.38	0.48 ± 0.03	-589	0.0009
PM-2.5 (grav)	0.36 ± 0.04	0.41 ± 0.30	0.05 [b]	-73	-	1.1 ± 0.33	1.1 ± 0.39	0.43 ± 0.06	-61	0.0021
PM-10 (spec)	0.38 ± 0.15	0.42 ± 0.14	0.11 ± 0.02	-85	0.0061	3.9 ± 1.55	4.3 ± 1.6	1.62 ± 0.08	-60	0.015
PM-10 (grav)	0.30 ± 0.07	0.24± 0.18	0.06 ± 0.03	-76	0.0218	2.9 ± 1.03	3.5 ± 1.4	1.49 ± 0.25	-53	0.015
VOC	0.07 ± 0.05	12 ± 9.4	0.09 ± 0.01	-99	0.243	63±74.5	26 ± 27	111.2± 58.7	151	0.445
Formaldehyde	14 ± 0.95	20 ± 5.9	14 ± 0.36	-15	0.351	25 ± 3.50	31 ± 10	23.4 ± 0.93	-16	0.221
NO_2	0.36 ± 0.06	0.35 ± 0.11	0.43 [b]	22	-	0.62 ± 0.13	0.35 ± 0.17	0.23 [b]	-53	-

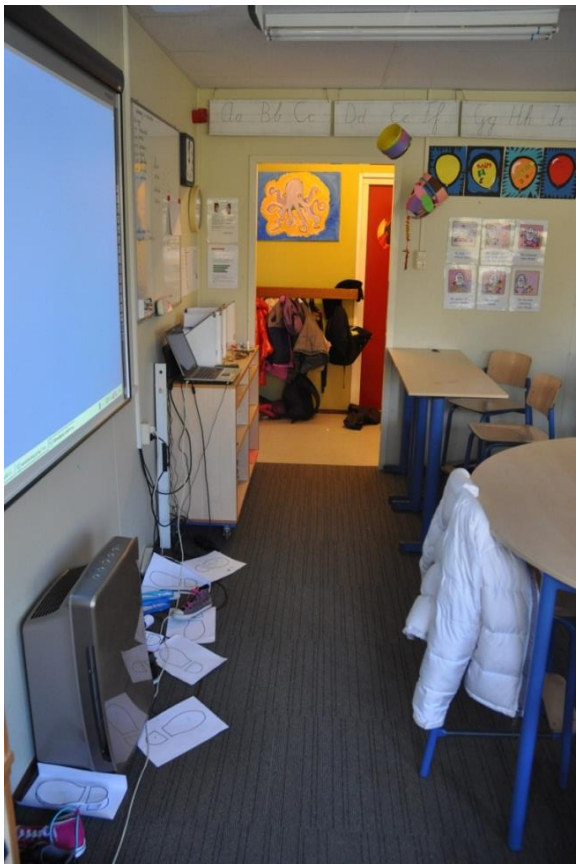
[a] Two-sided T-test on transformed data based comparison of average I/O ratios of both classrooms with and without interventions;

[b] Observation from classroom A was not available due to technical difficulties;

(a)

(b)

Figure S1: The main entrance of the semi-permanent unit with four classrooms (a) and the windows of the classrooms with the roller shutters (b)



(a)

(b)

Figure S2: Front of the classroom with below the smart-board and the air filtration unit (a) and back of the classroom with the air filtration unit and the air sampling equipment on a bookshelf (b)

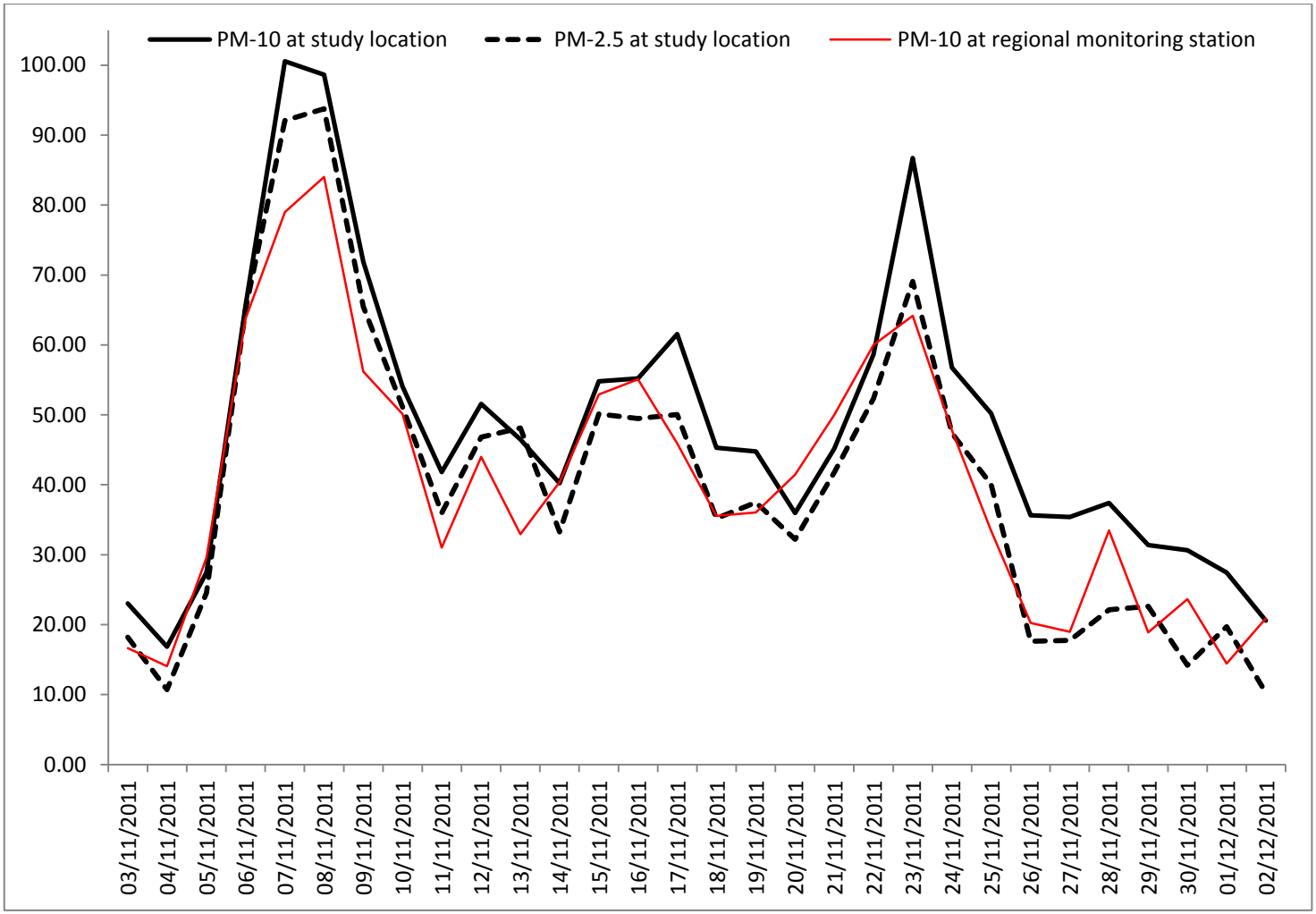


Figure S3: Day-average outdoor concentrations of PM-10 and PM-2.5 in µg/m^3 at the school at a regional air monitoring station (30 km NW of the study location).