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Scaling Factor: PM_{10} Versus TSP

Final Report

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U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards

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Introduction

Environmental Protection Agency (EPA) is in the process of deciding whether or not to permit Pb-PM_{10} sampling in lieu of Pb-TSP sampling. Permission rests on the ability of each monitoring location to estimate a scale factor for Pb-PM_{10} which can be used to predict the Pb-TSP concentration. As part of this process, data from monitoring locations with collocated Pb-TSP and Pb-PM_{10} FRM/FEM monitoring measurements were used to evaluate the relationship between Pb concentrations using the two monitoring methods.

This report is an exploratory investigation that evaluates the relationship by location using two different criteria for sampling frequency and data requirements for the calculation and acceptance of a valid scale factor. Proposed criteria are displayed in Table 1 and reflect two alternatives under consideration by EPA. One of these alternatives was published in the Federal Register on May 20, 2008, while the other was developed by an OAQPS staff member (Mr. Phil Lorang) as a possible alternative. The recommended approach, which employs the techniques of measurement error models, is demonstrated in Appendix A using the collocated data from a single location. A list of technical references on measurement error models is also provided in Appendix A.

Collocated Data Set

EPA, Research Triangle Park, NC, provided an initial collocated data set containing 48 locations. Measurements were taken from 1994 to 2006. No information regarding instrument detection limits or measurements below the detection limit were provided with the data set, therefore all data were used in the analyses. Of the initial 48 locations, only 21 met the quarterly sampling frequency criteria included in Table 1 for both alternatives of at least twelve pairs of collocated measurements for each of four consecutive quarters; and only one location met the monthly sampling criteria of at least 6 pairs of collocated measurement for at least 10 months in a 12 month period. Descriptive statistics for these 21 locations are provided in Table 2.

Criteria for the Use of a Scale Factor

If the quarterly sampling frequency criteria were met, the statistical criteria were calculated. These criteria include:

- each quarterly correlation coefficient ≥ 0.60; and
- each quarterly ratio, [average(TSP) / average(PM_{10})], within 20% of the yearly average ratio.

If the two quarterly criteria were met and if the yearly correlation coefficient ≥ 0.80, the scale factor is calculated as the yearly average ratio. The estimates of the statistical criteria for the 21 locations meeting the quarterly sampling frequency criteria are provided on pages 6 to 33.

If the monthly sampling frequency criteria were met, the statistical criteria were calculated. These criteria include:

- each monthly correlation coefficient ≥ 0.60; and
- each monthly ratio, [average(TSP) / average(PM_{10})], within 20% of the yearly average ratio.

If the two monthly criteria were met and if the yearly correlation coefficient ≥ 0.80, the scale factor is the yearly average ratio. The estimates of the statistical criteria for the one location meeting the monthly sampling frequency criteria are provided on page 34.

Conclusions

The quarterly statistical criteria were met for four out of the 21 locations:

- 060250008 for both years of data,
- 260770905 for all three years of data,
- 261630033 for three out of four years of data,
- 261390009 for the only year of data.

The monthly statistical criteria were met for the only location that met the sampling requirements:

- 261390009 for the only year of data.

Scatter plots of the collocated pairs by location reveal that the data from many locations (060130003, 060374002, 060750005, 060850004, 060853001, 170314201, 200570001, 201330002, 201730007, 201730008, 201730009, 201731012, 201770007, 201810001, 202090015, 270530053) are inappropriate for any statistical analyses that does not employ censoring methods. It is obvious from the "step like" patterns in many of the scatter plots that the data sets are comprised of large number of nondetect (censored) values. A more statistically rigorous approach that incorporates exploratory data analysis and imposes data requirements is discussed and illustrated in Appendix A.

Table 1. Criteria for the Use of Scaled Pb-PM_{10} Data as Surrogate Pb-TSP Data

Criteria	Lorang[1]	Federal Register[2]
Data Requirements	Use all reported data including zeros.	None.
Sampling Requirements	Minimum of at least 12 pairs of valid collocated measurements for each of four consecutive quarters. The requirement is based on a sampling frequency of 1 in 6.	Minimum of 12 consecutive months of collocated Pb-TSP and Pb-PM_{10} FRM/FEM monitoring which produces at least 6 pairs of valid collocated measurements for each of at least 10 months of each period of 12 months.
Correlation Requirements	Correlation coefficients ≥ 0.60 for each quarter containing at least 12 valid pairs and a correlation coefficient ≥ 0.80 for the 4 quarters in each 12 month period.	Correlation coefficients ≥ 0.60 for each month containing at least 6 valid pairs and a correlation coefficient ≥ 0.80 for the 10 or more months in each 12 month period.
Average Ratio Requirements	Each quarterly ratio, [ave(TSP) / ave(PM_{10})], shall be within 20% of the yearly average ratio. Round the quarterly ratios to two decimal places before making the comparisons.	Each monthly ratio, [ave(TSP) / ave(PM_{10})], shall be within 20% of the 10 month (11 or 12) average ratio. Round the monthly ratios to two decimal places before making the comparisons.
Scaling Factor Calculation	Rounded average of the quarterly unrounded ratios, [ave(TSP) / ave(PM_{10})].	Average of the monthly ratios, [ave(TSP) / ave(PM_{10})], using all 10 or more months with valid collocated measurements. Round the scaling factor to two decimal places.

[1] Phil Lorang, EPA, Research Triangle Park, NC

[2] Federal Register (Vol. 73, No. 98, Tuesday, May 20, 2008)

Table 2. Descriptive Statistic by Location for Collocated Pb-TSP and Pb-PM_{10} FRM/FEM Monitoring Measurements ($\mu g/m^3$).

Site	Years	N	Median		Range			
			TSP	PM_{10}	TSP		PM_{10}	
					Min.	Max.	Min.	Max.
060130003	94, 95, 96	172	0.010	0.010	0.010	0.010	0.010	0.020
060250005	97, 98	109	0.017	0.013	0.001	0.130	0.001	0.140
060374002	95, 97	108	0.020	0.008	0.000	0.200	0.001	0.190
060750005	94, 95, 96, 97	238	0.010	0.010	0.010	0.040	0.010	0.050
060850004	94, 95, 96, 97	243	0.010	0.010	0.002	0.050	0.001	0.050
060853001	94, 95, 96, 97	224	0.010	0.010	0.010	0.040	0.010	0.030
170314201	06	56	0.010	0.003	0.010	0.020	0.000	0.013
200570001	93	56	0.000	0.000	0.000	0.016	0.000	0.016
201330002	93	59	0.000	0.000	0.000	0.054	0.000	0.044
201730007	93, 95, 96, 97	232	0.000	0.000	0.000	0.037	0.000	0.020
201730008	93, 95, 96, 97	231	0.000	0.000	0.000	0.104	0.000	0.033
201730009	93, 95, 97	172	0.000	0.000	0.000	0.037	0.000	0.027
201731012	95, 96, 97	176	0.000	0.000	0.000	0.126	0.000	0.125
201770007	97	53	0.000	0.000	0.000	0.045	0.000	0.029
201810001	93, 94, 95, 96	234	0.000	0.000	0.000	0.074	0.000	0.051
202090015	93	57	0.017	0.011	0.000	0.087	0.000	0.067
202090020	97	52	0.016	0.012	0.000	3.739	0.000	2.647
260770905	93, 94, 95	181	0.011	0.008	0.000	0.125	0.000	0.127
261390009	00	111	0.010	0.006	0.000	0.100	0.000	0.104
261630033	03, 04, 05, 06, 07	296	0.016	0.014	0.002	0.225	0.002	0.144
270530053	97	53	0.000	0.005	0.000	0.040	0.000	0.020

Site 060130003 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
1994	1	14	0.010714	0.010714	1.000000	1.000000[1]
	2	13	0.010000	0.010000	1.000000	NA
	3	15	0.015333	0.012000	1.277778	0.582867
	4	14	0.014143	0.018571	0.761538	0.227305
1995	1	15	0.010000	0.010000	1.000000	NA
	2	14	0.011429	0.010714	1.066667	-0.113228
	3	16	0.010000	0.010000	1.000000	NA
	4	14	0.010143	0.010000	1.014286	NA
1996	1	13	0.010769	0.010769	1.000000	1.000000
	2	14	0.010714	0.010714	1.000000	-0.076923
	3	15	0.010000	0.010000	1.000000	NA
	4	15	0.011333	0.010933	0.964706	-0.104828

[1]Shaded cells meet the criteria the quarterly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria r ≥ 0.60.

Statistics by Year (Note: quarterly criteria not met.)

Year	N	Mean (µg/m^3)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
1994	56	0.012643	0.012857	0.983333	0.786667, 1.180000	0.312711
1995	59	0.010373	0.010169	1.020000	0.816000, 1.224000	-0.019938
1996	57	0.010596	0.010702	0.990164	0.792131, 1.188197	0.203682

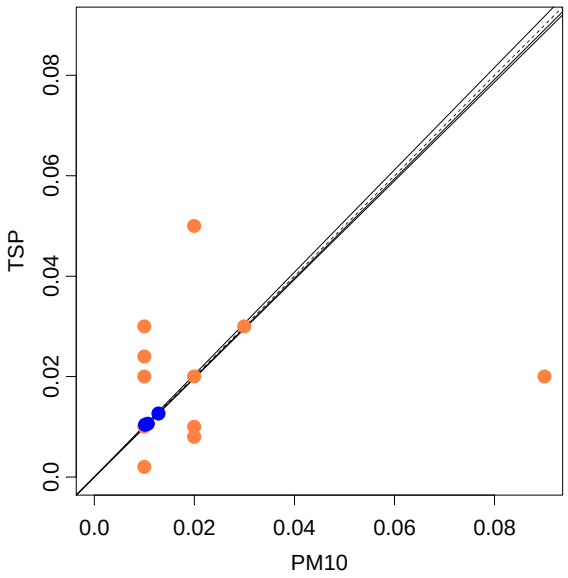
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 060250005 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
1997	1	14	0.018521	0.013643	1.357592	0.989692
	2	14	0.022400	0.018786	1.192395	0.994324
	3	13	0.025892	0.015638	1.565581	0.902012
	4	14	0.021821	0.018357	1.188716	0.986392
1998	1	13	0.022468	0.016692	1.344240	0.926085
	2	13	0.007992	0.006307	1.267073	0.839237
	3	14	0.017407	0.0132857	1.310215	0.941344
	4	14	0.024964	0.023500	1.062310	0.984529

[1]Shaded cells meet the criteria the quarterly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria r ≥ 0.60.

Statistics by Year (Note: quarterly criteria met for two out of two years.)

Year	N	Mean (µg/m^3)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
1997	55	0.022091	0.016836	1.312095	1.049676, 1.574514	0.956278
1998	54	0.018311	0.015074	1.214724	0.971793, 1.457690	0.950701

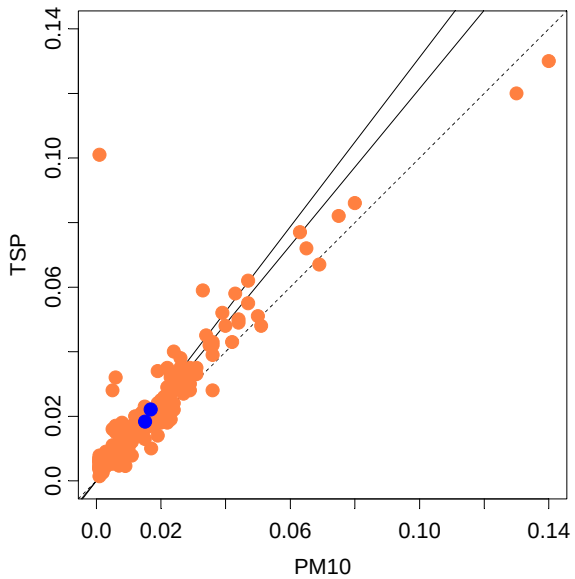
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 060374002 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
1995	1	13	0.024615	0.009923	2.480620	0.807934
	2	15	0.026667	0.006267	4.255319	0.274553
	3	15	0.028667	0.009333	3.071429	0.756708
	4	13	0.034154	0.021769	1.568905	0.843159
1997	1	12	0.030833	0.016167	1.907216	0.610494
	2	15	0.022000	0.005000	4.400000	0.647415
	3	13	0.018461	0.008615	2.142857	0.707332
	4	12	0.030000	0.020667	1.451613	0.064941

[1]Shaded cells meet the criteria the quarterly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria r ≥ 0.60.

Statistics by Year (Note: quarterly criteria not met.)

Year	N	Mean (µg/m^3)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
1995	56	0.0284643	0.011536	2.467492	1.973994, 2.960991	0.713123
1997	52	0.025000	0.012096	2.066773	1.653418, 2.480127	0.413227

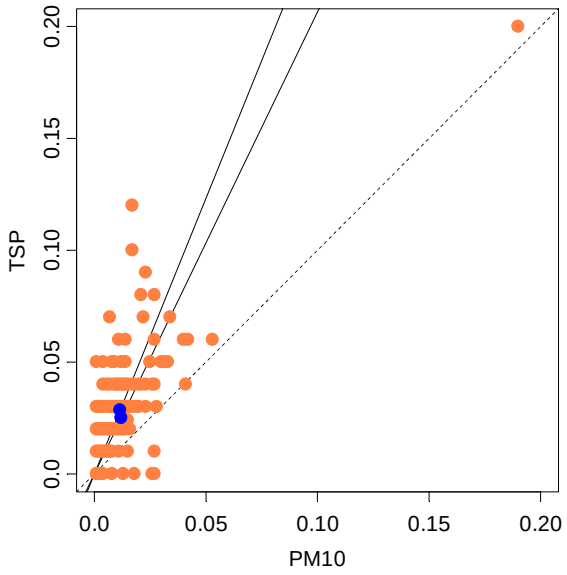
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 060750005 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
1994	1	15	0.013333	0.010667	1.250000	0.637059
	2	12	0.010000	0.010000	1.000000	NA
	3	16	0.014375	0.011250	1.277778	0.038778
	4	14	0.20000	0.016429	1.217391	0.542298
1995	1	15	0.012000	0.010667	1.125000	-0.133631
	2	15	0.012667	0.010667	1.187500	-0.161165
	3	16	0.013750	0.010000	1.375000	NA
	4	15	0.013667	0.014000	0.976190	-0.210042
1996	1	15	0.010667	0.010667	1.000000	-0.071429
	2	15	0.011000	0.010000	1.100000	NA
	3	15	0.012000	0.010000	1.200000	NA
	4	14	0.012143	0.012143	1.000000	0.575758
1997	1	15	0.010667	0.010000	1.066667	NA
	2	15	0.010267	0.010000	1.026667	NA
	3	15	0.010000	0.010000	1.000000	NA
	4	16	0.010000	0.010000	1.000000	NA

[1]Shaded cells meet the criteria the quarterly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria $r \geq 0.60$.

Site 060750005 - Quarterly Criteria (cont.)

Statistics by Year (Note: quarterly criteria not met.)

Year	N	Mean ($\mu g/m^3$)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
1994	57	0.014561	0.012105	1.202899	0.962319, 1.443478	0.533067
1995	61	0.0130328	0.011311	1.152174	0.921739, 1.382609	-0.113949
1996	59	0.011441	0.010678	1.071429	0.857143, 1.285714	0.255222
1997	61	0.010229	0.010000	1.022951	0.818361, 1.227541	NA

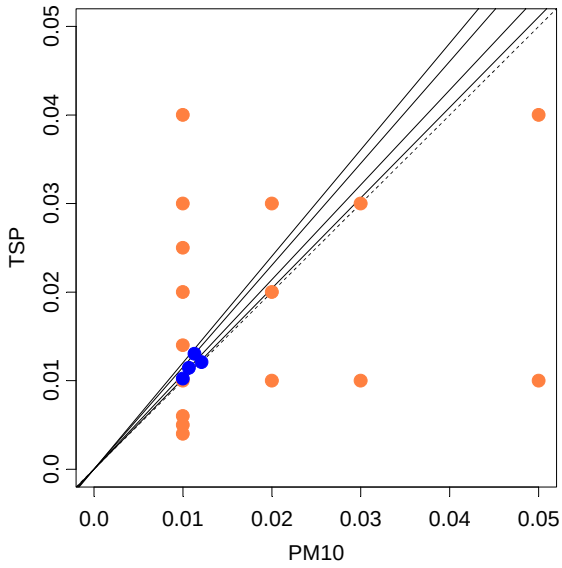
[1]Shaded cells meet the criteria $r \geq 0.80$.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 060850004 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
1994	1	13	0.016385	0.010769	1.521429	0.802094
	2	15	0.010000	0.010000	1.000000	NA
	3	16	0.015000	0.011875	1.263158	0.160128
	4	15	0.018000	0.018000	1.000000	0.374879
1995	1	15	0.010667	0.010667	1.000000	-0.071429
	2	16	0.013333	0.010000	1.333333	NA
	3	16	0.013125	0.010000	1.312500	NA
	4	15	0.0154667	0.010000	1.546667	NA
1996	1	16	0.011875	0.009750	1.217949	-0.329184
	2	15	0.010667	0.010000	1.066667	NA
	3	16	0.010625	0.010000	1.062500	NA
	4	15	0.014000	0.011333	1.235294	0.385164
1997	1	15	0.010667	0.010667	1.000000	-0.071429
	2	15	0.011067	0.010000	1.106667	NA
	3	15	0.010000	0.010000	1.000000	NA
	4	16	0.010000	0.010000	1.000000	NA

[1]Shaded cells meet the criteria the quarterly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria $r \geq 0.60$.

Site 060850004 - Quarterly Criteria (cont.)

Statistics by Year (Note: quarterly criteria not met.)

Year	N	Mean ($\mu g/m^3$)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
1994	59	0.014797	0.012712	1.164000	0.931200, 1.396800	0.429346
1995	61	0.013147	0.010164	1.293548	1.034839, 1.552258	-0.053956
1996	62	0.011774	0.010258	1.147799	0.918239, 1.377358	0.138526
1997	61	0.010426	0.010164	1.025806	0.820645, 1.230968	-0.024612

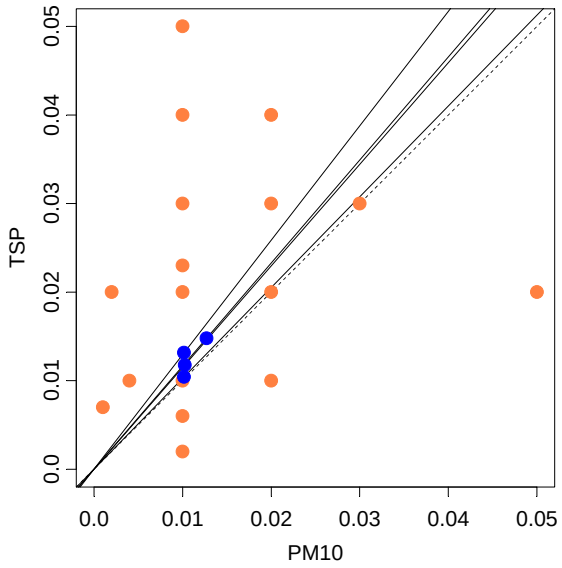
[1]Shaded cells meet the criteria $r \geq 0.80$.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 060853001 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
1994	1	14	0.010714	0.010000	1.071429	NA
	2	14	0.010000	0.010000	1.000000	NA
	3	16	0.011875	0.011250	1.055556	-0.181568
	4	14	0.014286	0.013571	1.052632	0.337349
1995	1	15	0.013333	0.010000	1.333333	NA
	2	15	0.010667	0.010000	1.066667	NA
	3	13	0.010714	0.010000	1.076923	NA
	4	14	0.010714	0.010000	1.071429	NA
1996	1	12	0.010833	0.010000	1.083333	NA
	2	12	0.010000	0.010000	1.000000	NA
	3	16	0.010000	0.010000	1.000000	NA
	4	12	0.0108333	0.012500	0.866667	-0.126660
1997	1	14	0.010000	0.010000	1.000000	NA
	2	15	0.010667	0.010667	1.000000	-0.071429
	3	13	0.010000	0.010000	1.000000	NA
	4	15	0.010000	0.010000	1.000000	NA

[1]Shaded cells meet the criteria the monthly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria $r \geq 0.60$.

Site 060853001 - Quarterly Criteria (cont.)

Statistics by Year (Note: quarterly criteria not met.)

Year	N	Mean ($\mu g/m^3$)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
1994	58	0.011724	0.011207	1.046154	0.836923, 1.255385	0.297965
1995	57	0.011403	0.010000	1.140351	0.912281, 1.368421	NA
1996	52	0.010385	0.010577	0.981818	0.785454, 1.178182	-0.037871
1997	57	0.010175	0.010175	1.000000	0.800000, 1.200000	-0.017857

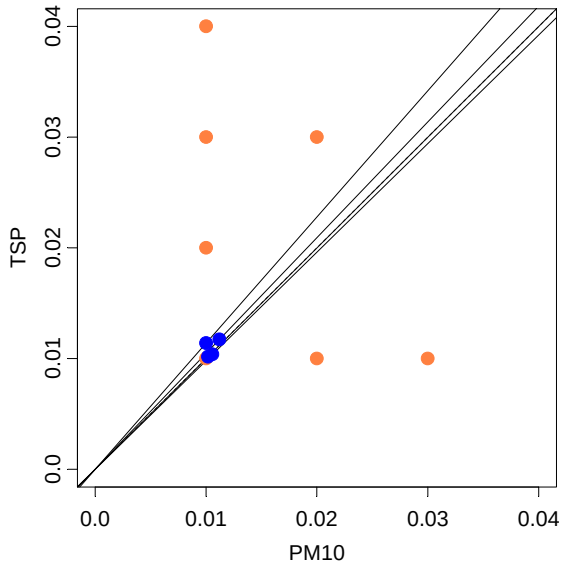
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 170314201 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
2006	1	13	0.010769	0.004434	2.428869	0.817232
	2	15	0.010000	0.003808	2.626050	NA
	3	13	0.010000	0.004996	2.001540	NA
	4	15	0.010000	0.004857	2.058743	NA

[1]Shaded cells meet the criteria the monthly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria r ≥ 0.60.

Statistics by Year (Note: quarterly criteria not met.)

Year	N	Mean (µg/m^3)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
2006	56	0.010179	0.004510	2.256800	1.805440, 2.708160	0.409187

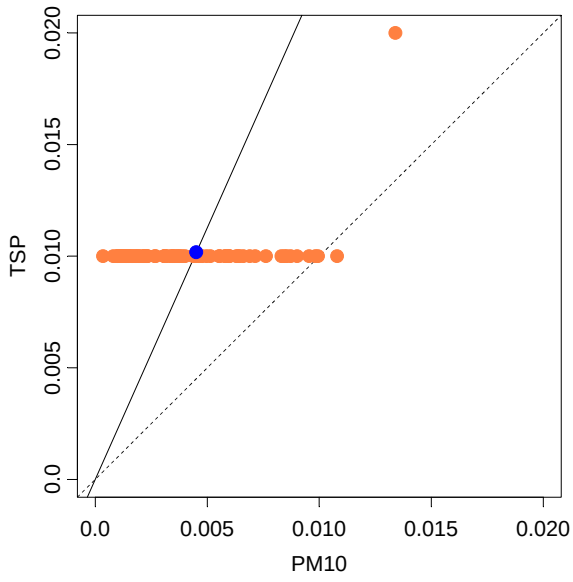
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 200570001 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
1993	1	14	0.002286	0.000000	NA	NA
	2	14	0.000786	0.000714	1.100000	-0.076923
	3	14	0.002143	0.000000	NA	NA
	4	14	0.002429	0.000000	NA	NA

[1]Shaded cells meet the criteria the monthly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria r ≥ 0.60.

Statistics by Year (Note: quarterly criteria not met.)

Year	N	Mean (µg/m^3)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
1993	56	0.001911	0.000179	10.700000	8.560000, 12.840000	-0.058012

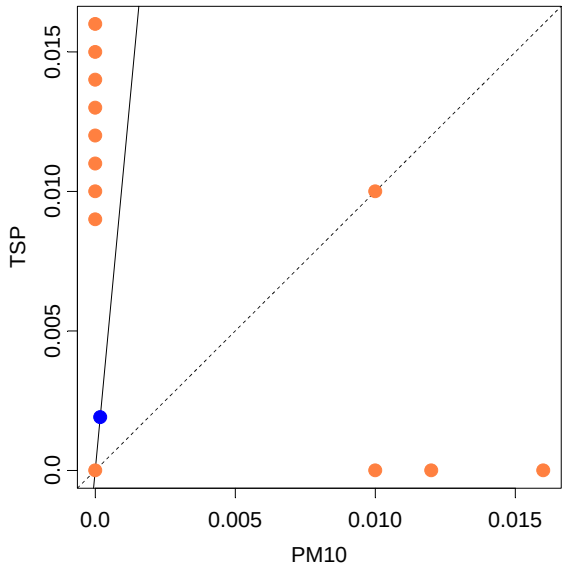
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 201330002 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
1993	1	14	0.001929	0.02357	0.818182	0.417272
	2	15	0.002000	0.000600	3.333333	0.659955
	3	15	0.001333	0.000000	NA	NA
	4	15	0.001200	0.001400	0.857143	-0.153645

[1]Shaded cells meet the criteria the monthly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria r ≥ 0.60.

Statistics by Year (Note: quarterly criteria not met.)

Year	N	Mean (µg/m^3)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
1993	59	0.001610	0.001068	1.507937	1.206349, 1.809524	0.270267

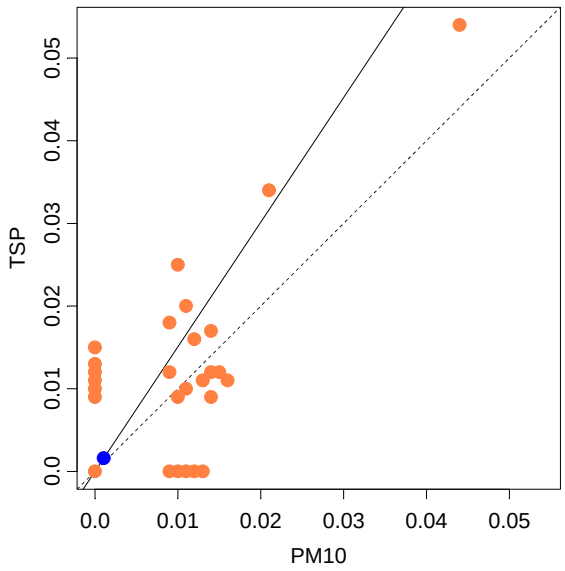
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 201730007 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
1993	1	13	0.016384	0.004462	3.672414	0.777531
	2	12	0.005167	0.000000	NA	NA
	3	15	0.007000	0.000000	NA	NA
	4	15	0.006267	0.003000	2.088889	0.398853
1995	1	15	0.006800	0.002533	2.684210	0.635168
	2	15	0.003933	0.001867	2.107143	-0.268883
	3	16	0.002625	0.002250	1.166667	0.109253
	4	15	0.002733	0.003933	0.694915	-0.090239
1996	1	15	0.008400	0.007733	1.086207	0.073774
	2	13	0.001077	0.001846	0.583333	-0.123091
	3	16	0.004187	0.003125	1.340000	0.034631
	4	14	0.004429	0.002500	1.771429	0.464190
1997	1	15	0.002467	0.000000	NA	NA
	2	12	0.006500	0.001917	3.391304	0.368682
	3	15	0.004000	0.002200	1.818182	0.000000
	4	16	0.002937	0.000625	4.700000	-0.148579

[1]Shaded cells meet the criteria the monthly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria $r \geq 0.60$.

Site 201730007 - Quarterly Criteria (cont.)

Statistics by Year (Note: quarterly criteria not met.)

Year	N	Mean (µg/m^3)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
1993	55	0.008618	0.001873	4.601942	3.681553, 5.522330	0.558223
1995	61	0.004000	0.002639	1.515528	1.212422, 1.818634	0.105134
1996	58	0.004638	0.003879	1.195556	0.956444, 1.434667	0.241256
1997	58	0.003828	0.001138	3.363636	2.690909, 4.036364	0.129748

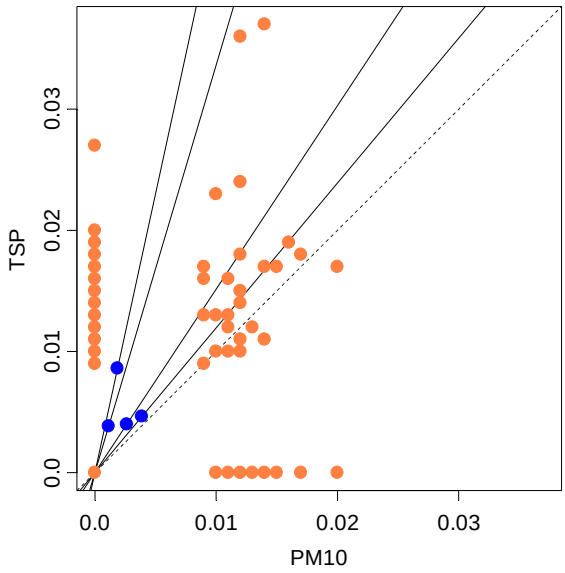
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 201730008 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
1993	1	14	0.013857	0.099286	1.492308	0.336438
	2	14	0.004500	0.001500	3.000000	0.070160
	3	15	0.000600	0.000000	NA	NA
	4	12	0.005250	0.001167	4.500000	0.510232
1995	1	15	0.005200	0.001600	3.250000	0.370369
	2	15	0.005667	0.004333	1.307692	0.640125
	3	16	0.002937	0.003687	0.796610	-0.115918
	4	14	0.003500	0.001286	2.722222	-0.253869
1996	1	14	0.003857	0.002357	1.636364	-0.313848
	2	15	0.004533	0.004067	1.114754	0.183802
	3	15	0.007000	0.002067	3.387097	-0.168308
	4	14	0.003786	0.000000	NA	NA
1997	1	14	0.000000	0.000000	NA	NA
	2	15	0.009133	0.002133	4.281250	-0.176631
	3	14	0.005571	0.000643	8.666667	-0.189445
	4	15	0.006733	0.001533	4.391304	0.592402

[1]Shaded cells meet the criteria the monthly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria $r \geq 0.60$.

Site 201730008 - Quarterly Criteria (cont.)

Statistics by Year (Note: quarterly criteria not met.)

Year	N	Mean (µg/m^3)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
1993	55	0.005982	0.003000	1.993939	1.595152, 2.392727	0.549225
1995	60	0.004317	0.002767	1.560241	1.248193, 1.872289	0.225052
1996	58	0.004828	0.002155	2.240000	1.792000, 2.688000	-0.049561
1997	58	0.005448	0.001103	4.937500	3.950000, 5.925000	0.013913

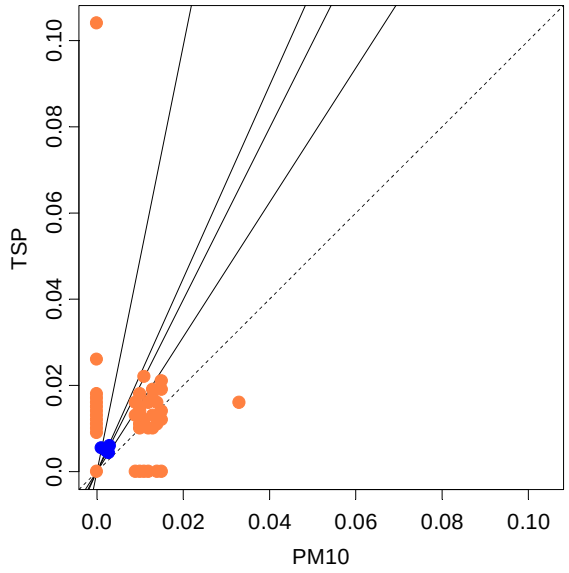
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 201730009 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
1993	1	14	0.011333	0.002600	4.358974	0.543207
	2	14	0.007750	0.002833	2.735294	0.498580
	3	15	0.004571	0.000000	NA	NA
	4	12	0.008867	0.001133	7.823529	0.579067
1995	1	15	0.003800	0.001400	2.714286	0.537303
	2	15	0.008200	0.002833	2.911765	0.105723
	3	16	0.004937	0.000750	6.583333	-0.193441
	4	14	0.004267	0.002267	1.882353	0.381482
1997	1	14	0.005867	0.002467	2.378378	0.532259
	2	15	0.002714	0.000000	NA	NA
	3	14	0.002571	0.000714	3.600000	-0.143578
	4	15	0.002800	0.000600	4.666667	-0.126323

[1]Shaded cells meet the criteria the monthly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria r ≥ 0.60.

Statistics by Year (Note: quarterly criteria not met.)

Year	N	Mean (µg/m^3)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
1993	56	0.008214	0.001607	5.111111	4.088889, 6.133333	0.490580
1995	58	0.005155	0.001741	2.960396	2.368317, 3.552475	0.229751
1997	58	0.003517	0.000965	3.642857	2.914286, 4.371429	0.301734

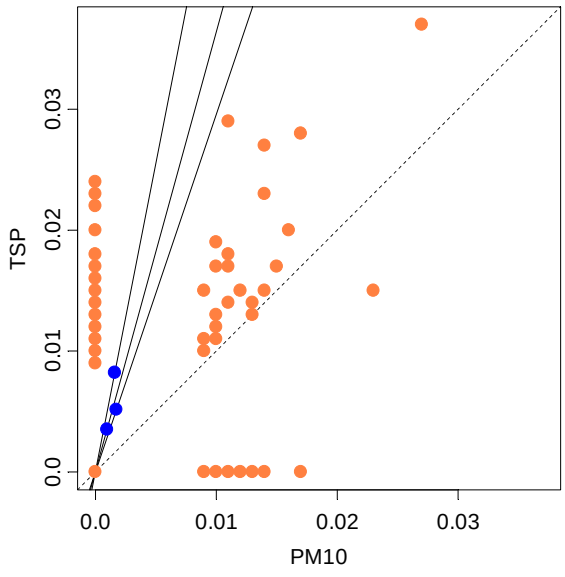
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 201731012 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
1995	1	15	0.002800	0.003800	0.736842	0.288690
	2	13	0.001538	0.002692	0.571429	0.324836
	3	16	0.010812	0.012437	0.869347	0.954722
	4	15	0.010000	0.005000	2.000000	0.448503
1996	1	15	0.014333	0.005733	2.500000	0.783670
	2	14	0.003357	0.004071	0.824561	-0.145163
	3	13	0.005769	0.001154	5.000000	0.547347
	4	15	0.006400	0.001533	4.173913	0.471077
1997	1	14	0.001643	0.000714	2.300000	-0.110230
	2	15	0.004400	0.000000	NA	NA
	3	15	0.005400	0.004200	1.285714	0.267291
	4	16	0.005375	0.005812	0.924731	0.608601

[1]Shaded cells meet the criteria the monthly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria r ≥ 0.60.

Statistics by Year (Note: quarterly criteria not met.)

Year	N	Mean (µg/m^3)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
1995	59	0.006525	0.006203	1.051913	0.841530, 1.262295	0.887712
1996	57	0.007596	0.003175	2.392265	1.913812, 2.870718	0.585816
1997	60	0.004267	0.002767	1.542169	1.233735, 1.850602	0.344304

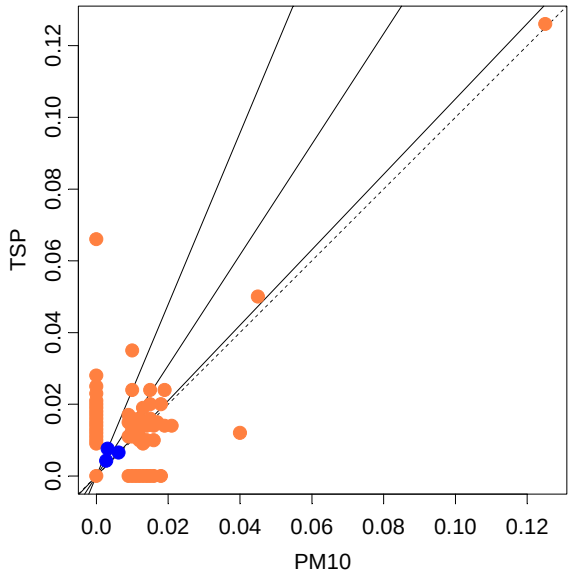
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 201770007 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
1997	1	12	0.000000	0.001917	0.000000	NA
	2	13	0.007000	0.003538	1.978261	0.375339
	3	13	0.003846	0.004461	0.862069	0.413037
	4	15	0.004867	0.004867	1.000000	0.419803

[1]Shaded cells meet the criteria the monthly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria r ≥ 0.60.

Statistics by Year (Note: quarterly criteria not met.)

Year	N	Mean (µg/m^3)		Ratio = average(TSP) / average(PM_{10})]	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
1997	53	0.004037	0.003773	1.070000	0.856000, 1.284000	0.386956

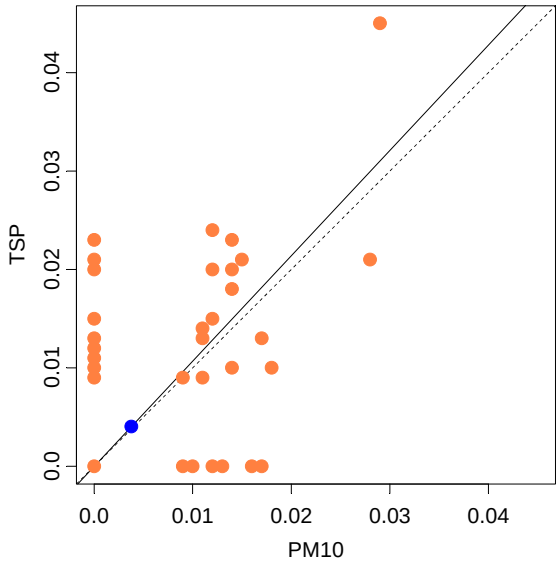
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 201810001 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
1993	1	15	0.002800	0.001733	1.615385	0.599157
	2	15	0.002867	0.001267	2.263158	0.188480
	3	14	0.001286	0.000000	NA	NA
	4	15	0.003267	0.004333	0.753846	0.445317
1994	1	15	0.002867	0.002267	1.264706	-0.022131
	2	12	0.002833	0.001500	1.888889	-0.254412
	3	16	0.000875	0.000875	1.000000	-0.066667
	4	15	0.000000	0.000000	NA	NA
1995	1	15	0.002267	0.000000	NA	NA
	2	15	0.001467	0.000000	NA	NA
	3	15	0.003800	0.003467	1.096154	0.960001
	4	14	0.000643	0.001214	0.529412	-0.076923
1996	1	15	0.001200	0.001000	1.200000	-0.104828
	2	12	0.001583	0.000000	NA	NA
	3	16	0.003875	0.003062	1.265306	-0.079160
	4	15	0.001600	0.000000	NA	NA

[1]Shaded cells meet the criteria the monthly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria $r \geq 0.60$.

Site 201810001 - Quarterly Criteria (cont.)

Statistics by Year (Note: quarterly criteria not met.)

Year	N	Mean (µg/m^3)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
1993	59	0.002576	0.001864	1.381818	1.105455, 1.658182	0.416940
1994	58	0.001569	0.001138	1.378788	1.103030, 1.654545	-0.017092
1995	59	0.002068	0.001169	1.768116	1.414493, 2.121739	0.711110
1996	58	0.002121	0.001103	1.921875	1.537500, 2.306250	0.015136

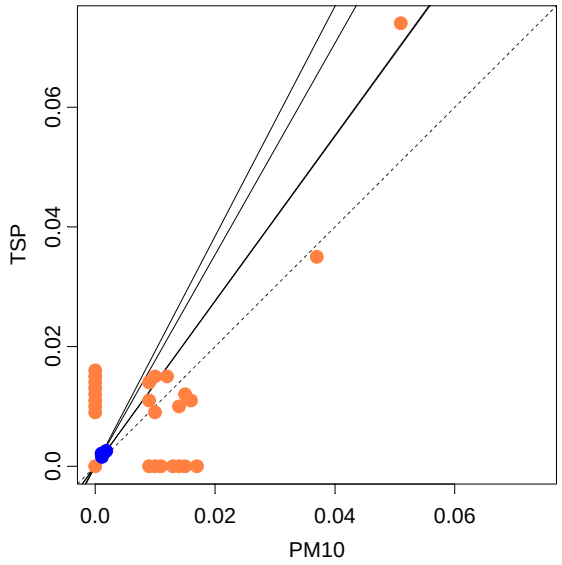
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 202090015 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
1993	1	15	0.029600	0.016600	1.783133	0.921275
	2	16	0.014625	0.005187	2.819277	0.649055
	3	12	0.018167	0.009833	1.847458	0.771688
	4	14	0.020357	0.013429	1.515957	0.676434

[1]Shaded cells meet the criteria the monthly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria r ≥ 0.60.

Statistics by Year (Note: quarterly criteria not met.)

Year	N	Mean (µg/m^3)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
1993	57	0.020719	0.011193	1.851097	1.480878, 2.221317	0.842225

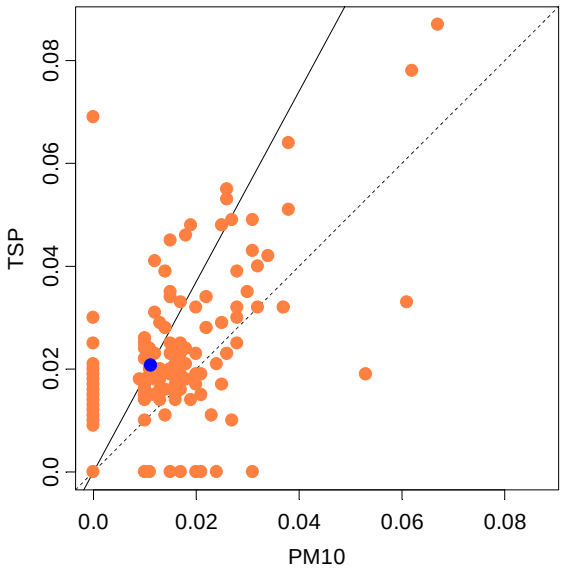
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 202090020 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
1997	1	12	0.051333	0.032500	1.579487	0.296985
	2	13	0.032538	0.017077	1.905405	0.609623
	3	14	0.030071	0.014143	2.126263	0.971074
	4	13	0.442538	0.317538	1.393653	0.999672

[1]Shaded cells meet the criteria the monthly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria r ≥ 0.60.

Statistics by Year (Note: quarterly criteria not met.)

Year	N	Mean (µg/m^3)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
1997	52	0.138711	0.094961	1.460713	1.168570, 1.752855	0.998208

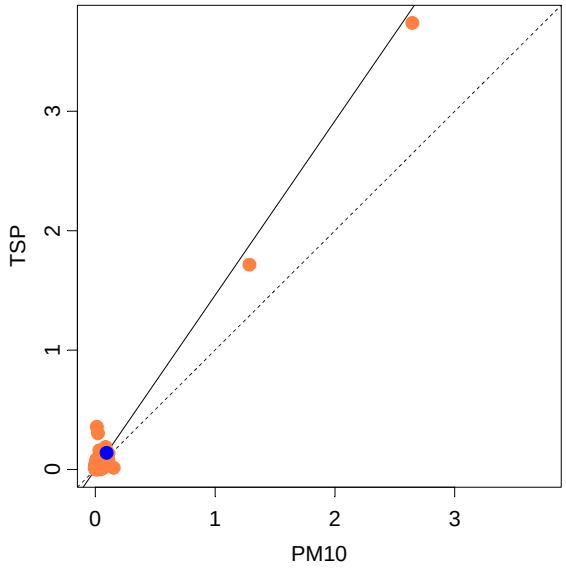
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 260770905 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
1993	1	15	0.018200	0.154667	1.176724	0.997062
	2	16	0.018687	0.017000	1.099265	0.995068
	3	15	0.014467	0.010933	1.323171	0.886996
	4	15	0.011267	0.008733	1.290076	0.957378
1994	1	15	0.012867	0.010667	1.206250	0.975968
	2	14	0.011429	0.008571	1.333333	0.949831
	3	15	0.014067	0.011400	1.233918	0.865198
	4	15	0.0124000	0.010200	1.215686	0.953857
1995	1	15	0.009467	0.008000	1.183333	0.903398
	2	15	0.009600	0.007667	1.252174	0.921196
	3	16	0.014250	0.011375	1.252747	0.889537
	4	15	0.0128000	0.010533	1.215190	0.957421

[1]Shaded cells meet the criteria the monthly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria $r \geq 0.60$.

Statistics by Year (Note: quarterly criteria met for all three years.)

Year	N	Mean (µg/m^3)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
1993	61	0.015705	0.013098	1.198999	0.959199, 1.438798	0.991117
1994	59	0.012712	0.010237	1.241722	0.993377, 1.490066	0.952516
1995	61	0.011574	0.009426	1.227826	0.982261, 1.473391	0.926083

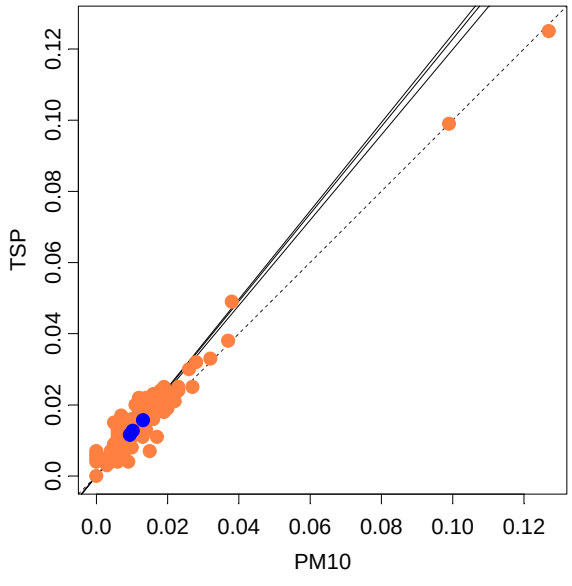
[1]Shaded cells meet the criteria $r \geq 0.80$.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 261390009 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
2000	1	27	0.013333	0.009037	1.475410	0.850299
	2	28	0.011043	0.008043	1.373002	0.952789
	3	27	0.013111	0.008963	1.462810	0.943179
	4	29	0.008931	0.006345	1.407609	0.910667

[1]Shaded cells meet the criteria the monthly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria r ≥ 0.60.

Statistics by Year (Note: quarterly criteria met.)

Year	N	Mean (µg/m^3)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
2000	111	0.011551	0.008065	1.432306	1.145845, 1.718767	0.915555

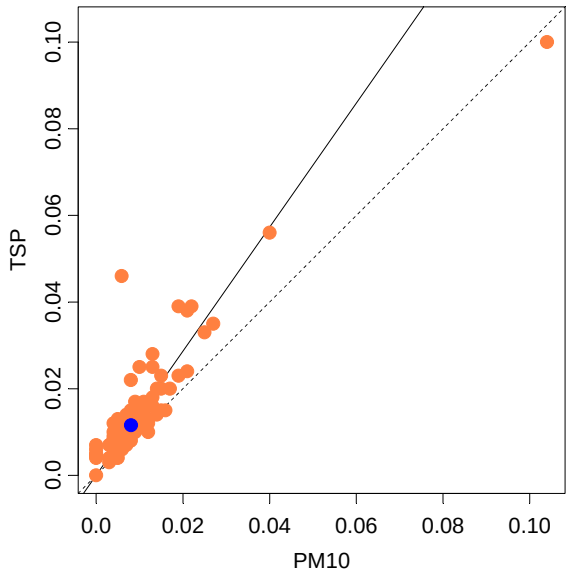
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 261630033 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
2003	1	15	0.020968	0.018491	1.133967	0.977723
	2	15	0.027569	0.019923	1.138371	0.933253
	3	16	0.039375	0.036043	1.092441	0.502381
	4	15	0.019173	0.024642	0.778048	0.884073
2004	1	15	0.013921	0.012445	1.118659	0.945503
	2	12	0.017982	0.016432	1.094275	0.846323
	3	16	0.018746	0.019171	0.977831	0.903862
	4	15	0.025893	0.023042	1.123745	0.985550
2005	1	15	0.020491	0.018589	1.102230	0.966472
	2	12	0.019813	0.018425	1.075350	0.952798
	3	15	0.022973	0.020356	1.128578	0.981802
	4	17	0.021823	0.015517	1.406422	0.905175
2006	1	13	0.021623	0.020711	1.044050	0.982651
	2	15	0.029087	0.019957	1.457442	0.985619
	3	15	0.019745	0.018273	1.080518	0.989525
	4	16	0.017097	0.016295	1.049248	0.991820
2007	1	15	0.018115	0.016661	1.087228	0.992292
	2	15	0.024159	0.021804	1.107992	0.992228
	3	14	0.016771	0.013677	1.226238	0.977298
	4	15	0.017628	0.015405	1.144329	0.985820

[1]Shaded cells meet the criteria the monthly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria $r \geq 0.60$.

Site 261630033 - Quarterly Criteria (cont.)

Statistics by Year (Note: quarterly criteria met for three out of four years.)

Year	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
2003	61	0.026978	0.024960	1.080858	0.864687, 1.297030	0.707908
2004	58	0.019186	0.017866	1.074028	0.859222, 1.288834	0.963683
2005	59	0.021368	0.018120	1.179279	0.943423, 1.415135	0.938935
2006	59	0.021816	0.018702	1.166491	0.933193, 1.399790	0.9309116
2007	59	0.019168	0.016941	1.133853	0.907082, 1.360623	0.986875

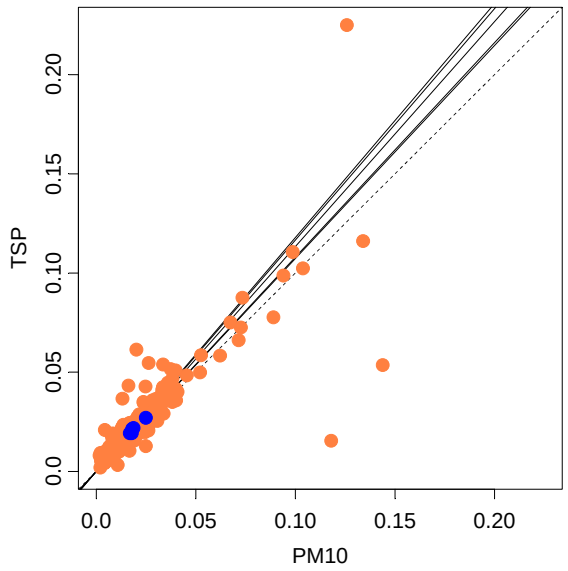
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 270530053 - Quarterly Criteria

Statistics by Year x Quarter

Year	QTR	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
1997	1	12	0.000000	0.001917	0.000000	NA
	2	13	0.007000	0.003538	1.978261	0.375339
	3	13	0.003846	0.004461	0.862069	0.413037
	4	15	0.004867	0.004867	1.000000	0.419803

[1]Shaded cells meet the criteria the monthly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria r ≥ 0.60.

Statistics by Year (Note: quarterly criteria not met)

Year	N	Mean (µg/m^3)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r^2][1]
		TSP	PM_{10}			
1997	53	0.004037	0.003773	1.070000	0.856000, 1.284000	0.386956

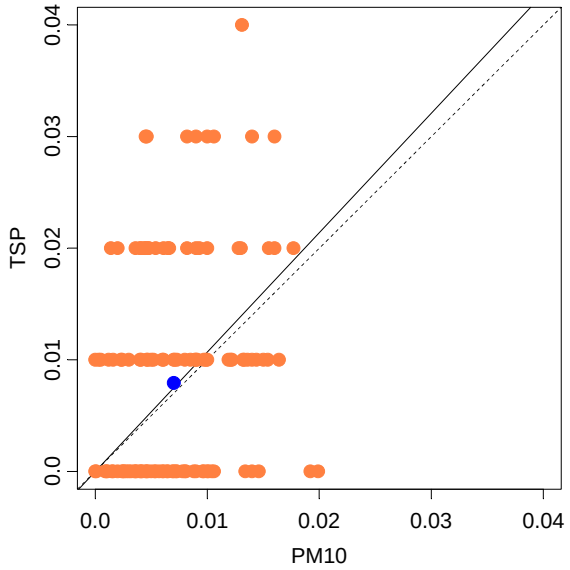
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Site 261390009 - Monthly Criteria

Statistics by Year x Quarter

Year	MN	N	Mean (µg/m^3)		Ratio[1] = average(TSP) / average(PM_{10})	[r][2]
			TSP	PM_{10}		
2000	1	7	0.017143	0.012143	1.411765	0.944590
	2	9	0.008444	0.006778	1.245902	0.849385
	3	11	0.014909	0.008909	1.673469	0.583507
	4	10	0.014300	0.010400	1.375000	0.971654
	5	10	0.010900	0.008000	1.362500	0.934042
	6	8	0.007150	0.005150	1.388350	0.717249
	7	8	0.011500	0.008000	1.437500	0.929801
	8	9	0.015222	0.011111	1.370000	0.984003
	9	10	0.012500	0.007800	1.602564	0.961398
	10	10	0.011800	0.008900	1.325843	0.900189
	11	10	0.008000	0.005400	1.481481	0.979898
	12	9	0.006778	0.004556	1.487805	0.739876

[1]Shaded cells meet the criteria the monthly ratio is within a 20% interval around the yearly ratio.
[2]Shaded cells meet the criteria r ≥ 0.60.

Statistics by Year (Note: monthly criteria met.)

Year	N	Mean (µg/m^3)		Ratio = average(TSP) / average(PM_{10})	Ratio ± 20%	[r][1]
		TSP	PM_{10}			
2000	111	0.011551	0.008065	1.432306	1.145845, 1.718767	0.915555

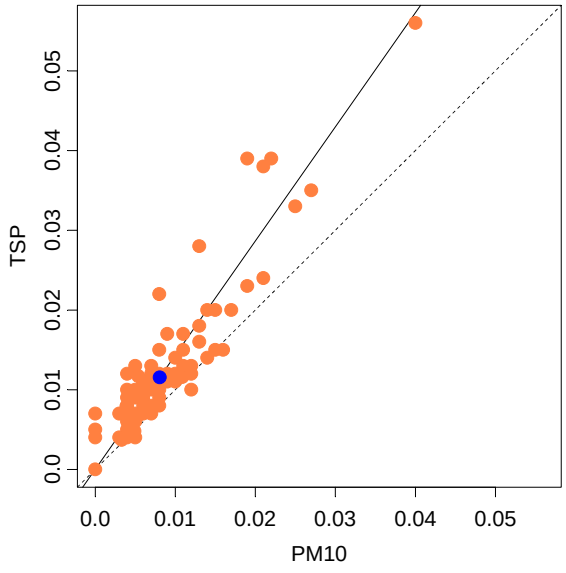
[1]Shaded cells meet the criteria r ≥ 0.80.

TSP versus PM_{10} pairs
(orange filled circles)

TSP versus PM_{10} yearly means
(blue filled circles)

Dotted Reference line
(slope = 1, intercept = 0)

Solid line with Yearly Ratio Slope
(intercept = 0)



Appendix A. An alternative approach to developing a scale factor between Pb-TSP and Pb-PM_{10} FRM/FEM.

Concerns about the two proposed methods (Table 1) for estimating the scale factor include:

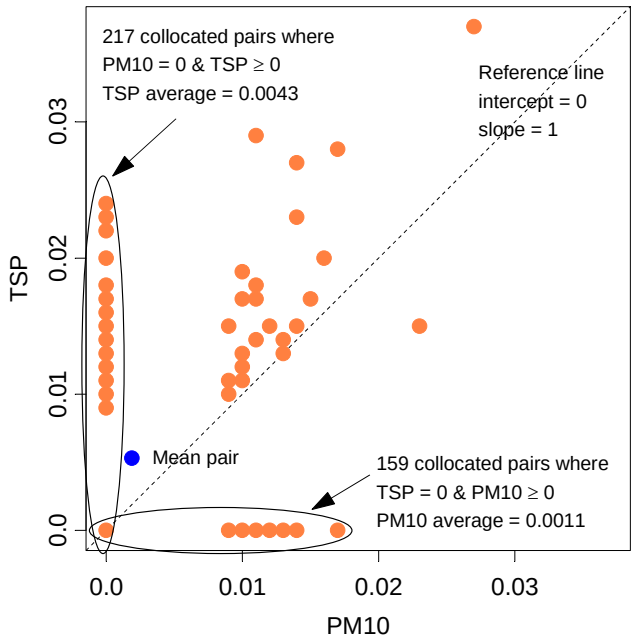
- All data are being included in the estimation of the scale factor. There is no way to estimate the impact of nondetect measurements on the scale factor since it appears the method for dealing with nondetects is site dependent.
- The scale factor will be used for prediction, but there is no way to estimate the variability in the predicted value.
- It appears the scale factor will be used to estimate outside the range of the Pb-PM_{10} and Pb-TSP measurements used to construct the scale factor. Estimation is only valid within the range of the values used to construct the parameter estimates. At higher concentrations the relationship between Pb-PM_{10} and Pb-TSP may change.
- No justification is being provided for why it is appropriate to assume the intercept is zero.
- These two methods are not defensible.

This appendix outlines the recommended approach which first incorporates exploratory data analysis methods to evaluate the data for outliers and censoring; and a parameter estimation method that takes into account the fact that both variables are measured with error. The collocated data from site 201730009 is used to illustrate the alternative approach; the data from all three years are combined.

Step 1:
Plot the data. Modeling should never be attempted without first visualizing the data. Below is a scatter plot of all the collocated data for site 201730009 (n = 256).

Observations about the figure:

- There appears to be a linear relationship in some portion of the data.
- There appears to be a large portion of the data that are below the detection limit.
- Assuming that collocated pairs where either measurement is zero are below the detection limit and are not appropriate for model building, it appears that a scale factor for transforming PM10 to TSP will be greater than one, if the intercept is zero.



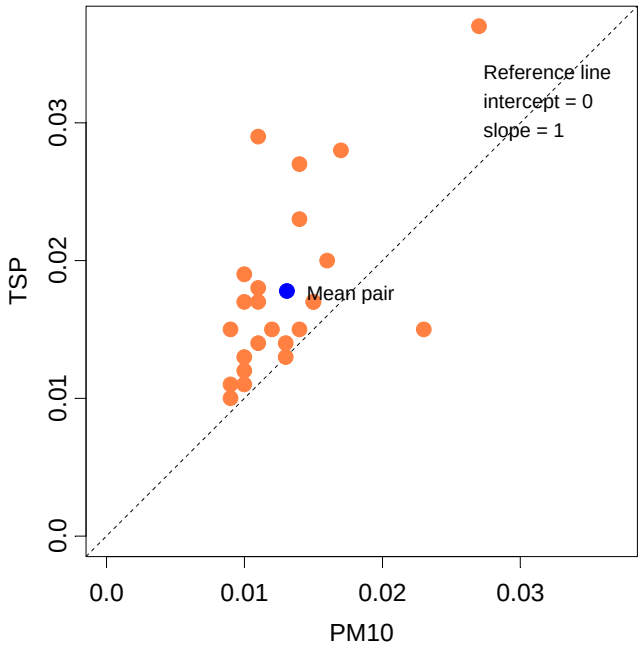
Data removed from the analyses (n = 232 pairs):

- 144 pairs where both Pb-TSP and Pb-PM_{10} are equal to zero
- 15 pairs where Pb-TSP is equal to zero and Pb-PM_{10} ranges from 0.009 to 0.017.
- 73 pairs where Pb-PM_{10} is equal to zero and Pb-TSP ranges from 0.009 to 0.024.

Step 2:
Remove data below the detection limit – they cannot be used for model building. Using nondetects in the estimation of a scaling factor will lead to a biased estimate. One reason is that the detection limits for the two methods are different.

Observations about the figure:

- Once the nondetect values are removed from the analyses (n=24), note how the location of the mean pair changes. The ratio of the average (TSP) / average(PM10) with the nondetects included is 2.806 and without the nondetects the ratio is 1.360.



Data used in the analyses (n = 24 pairs):

Monitor	N	Minimum	Median	Mean	Maximum	Std. Dev.
TSP	24	0.010	0.016	0.018	0.037	0.007
PM_{10}	24	0.009	0.001	0.013	0.027	0.004

Step 3:
Treat this as a statistical estimation problem where both analytic methods are measured with error. References that describe the methodology include:

Fuller, W. A. (2006). *Measurement Error Models*. John Wiley & Sons, New York.

Graybill, F. A. (1961). *An Introduction to Linear Statistical Models*. Volume I. McGraw-Hill Book Company, Inc., New York. Chapter 9, 186 – 194.

MacTaggart, D. L. and Farwell, S. O. (1992). Analytical Use of Linear Regression. Part II: Statistical Error in Both Variables. *Journal of AOAC International*, 75, 608 – 614.

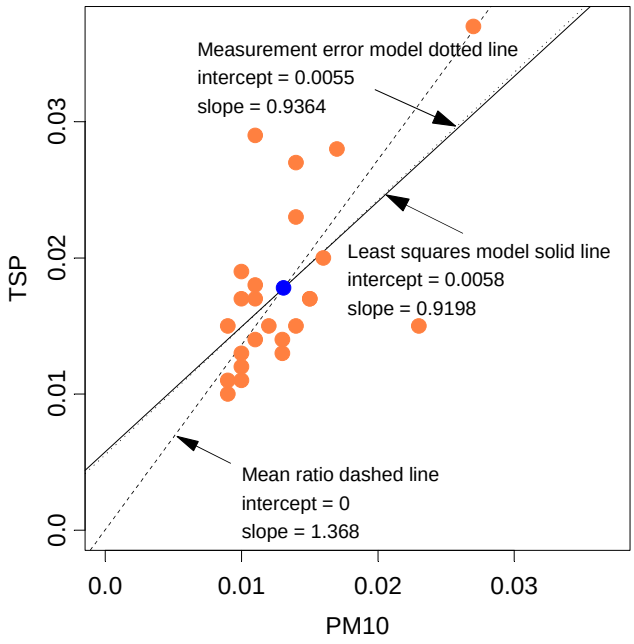
Ripley, B. D. and Thompson, M. (1987). Regression Techniques for the Detection of Analytical Bias. *Analyst*, 112, 377 – 383.

Sprent, P. (1990). Some History of Functional and Structural Relationships. *Contemporary Mathematics 112, Statistical Analysis of Measurement Error Models and Application*, Philip J. Brown and Wayne Fuller, Editors. 3-15.

The data from site 201730009 (without the nondetects) is used to construct a model to describe the relationship between the two random variables, Pb-PM_{10} and Pb-TSP. The traditional method for estimating the parameters of a linear model, least squares, is used as well as an estimation method that takes into account the fact that the predictor variable (in this case PM10) is measured with error.

Observations about the figure:

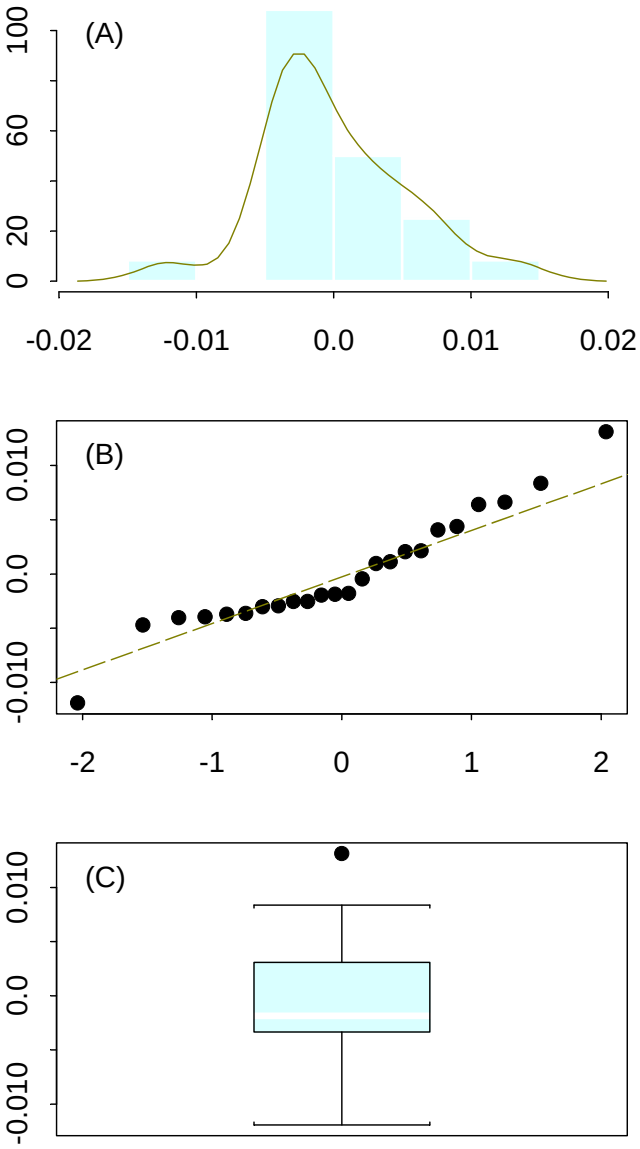
- The parameter estimates using least squares and measurement error model methods are very similar. The parameter estimates using the ratio of the means would underestimate at low concentrations (PM10 < 0.013) and over estimate at high concentrations (PM10 > 0.013).



Step 4:
Check the residuals from the model to make sure the assumptions of normality and homogeneity of variance are met. The residuals are plotted below, along with descriptive statistics and diagnostic inferential tests. Based on the histogram (A), q-q plot (B), and box plot (C), there does not appear to be any violation of the model assumption of normality (see page 41 for guidance on how to interpret these plots for normality). The D'Agostino & Pearson test for normality verify these observations. The test provides a test statistic of K2 = 2.4578 and p-value = 0.2926; one would fail to reject the null hypothesis that the residuals are normally distributed.

Descriptive Statistics:
N = 24
Min. = -0.0119
Q(.25) = -0.0032
Median = -0.0018
Q(.75) = 0.0026
Max. = 0.0131
Mean = 0
SD = 0.0053
CS = 0.4369
CK = 3.5733
CV = NA

D'Agostino & Pearson Test for Normality:
K2 = 2.4578
p(K2) = 0.2926
Z(CS) = 1.0285
p(Z(CS)) = 0.1519
Z(CK) = 1.1833
p(Z(CK)) = 0.1184



Acronyms, description of statistics and how to interpret the figures in Step 4:

Descriptive Statistics

N	sample size
Min.	minimum value of a set of observations
Q(.25)	25^{th} quantile; divides the data set such that one fourth of the observations fall below Q(.25) and three fourths lie above
Median	50^{th} quantile; divides the data set such that one half of the observations fall below Q(.50) and one half lie above
Q(.75)	75^{th} quantile; divides the data set such that three fourths of the observations fall below Q(.75) and one fourth lie above
Max.	maximum value of a set of observations
Mean	the arithmetic average of all the values in a set of observations; the mean is the most commonly used measure of central tendency.
SD	the standard deviation describe the dispersion relative to the center of a set of observations; the variance is the average of the squared deviation of each observation from the mean; the standard deviation is the square root of the variance
CS	coefficient of skewness; the third moment about the mean is a measure of asymmetry; symmetrical distributions will have a skewness of 0, distributions that are skewed to the left will have a skewness < 0, and distributions that are skewed to the right will have a skewness > 0
CK	coefficient of kurtosis; the fourth moment about the mean is a measure of curvature or kurtosis, which is the degree of flatness of a density near its center; values close to $3(n - 1)/(n + 1)$ indicate normality
CV	coefficient of variation; the mean divided by the standard deviation

D'Agostino & Pearson Test for Normality

K2	the test statistic for an omnibus test of normality based on the coefficients of skewness and kurtosis; the null hypothesis is that the data are normally distributed
p(Z(K2))	the probability of observing a value of Z(CS) or one greater
Z(CS)	the test statistic for an inferential test for detecting nonnormality due to skewness; the null hypothesis is the CS = 0
p(Z(CS))	the probability of observing a value of Z(CS) or one greater
Z(CK)	the test statistic for an inferential test for detecting nonnormality due to kurtosis; the null hypothesis is the CK = 3
p(Z(CK))	the probability of observing a value of Z(CK) or one greater

Figures

(A) A ***histogram*** partitions the range of the data into several nonoverlapping intervals of equal length, called bins, and counts the number observations in each bin. The number of counts in each bin can be displayed on a density scale, where the y-axis represents the probability; or a nondensity or frequency scale, where the y-axis represents the bin counts. The histogram is completely determined by two parameters, the *bin width* and the *bin origin*.

The histogram of a set of observations that are normally distributed will appear unimodal and symmetric.

(B) A ***normal quantile-quantile plot (Q-Q plot)*** is obtained by plotting the quantiles of the observed data against the corresponding quantiles of the normal distribution. If the quantiles of the empirical distribution and the quantiles of the normal distribution, fall on a straight line then the distributions are similar.

(C) A ***box plot*** is a rectangle, the top and bottom of the rectangle represent the upper and lower quartiles of the data, the horizontal line within the rectangle represents the median. Lines, in the shape of a "T", extend from the box to the nearest value not beyond a *standard span* from the quartiles. These lines are often referred to as whiskers. Values beyond the end of the whiskers are drawn individually.

The ***standard span*** is 1.5·Inter-Quartile Range (IQR) , where the *upper quartile* is the 75^{th} quantile, Q(.75), the *lower quartile* is the 25^{th} quantile, Q(.25) and the $IQR = Q(.75) - Q(.25)$.

The box plot of a set of observations that are normally distributed will be symmetric with the median in the center of the box.