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Atmospheric Measurement Techniques Discussions
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Interactive comment on "Using Low Cost Sensors to Measure Ambient Particulate Matter Concentrations and On-Road Emissions Factors" *by* K. K. Johnson et al.

Anonymous Referee #5

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General comments

The manuscript *Using Low Cost Sensors to Measure Ambient Particulate Matter Concentrations and On-Road Emissions Factors* promises to evaluate a number of low-cost PM sensors under a variety of conditions. However, I find several important problems with the methods employed in this work:

1) From my understanding of the text and photographs in Figures 1 and 2, PM measurements are performed by using a fan to blow ambient air over passive optical sensors. In my view, this is a very poor way to conduct particle sampling. What effect does the fan have on particle concentration and size distribution entering the sampling box? There is no way that the fan blades aren't acting as impactors and filtering particles

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in some (unknown) way. The fans should have been on the exhaust end of the box pulling air through the sensors instead. Also, Figure 1 doesn't actually show where the inlet fan is located. Figure 2 seems to have circuit boards of different colors in the two photographs - this should be explained in the figure caption (are they different sensors or is this just an artifact of the photographs?).

2) The "calibration" presented here isn't really a calibration, but rather a correlation. Page 6 line 6 says that the entire dataset is used as a calibration - then what is used for analysis? You can't find the best regression between two datasets then plot the same data next to each other with the regression applied and say that they match well. In this case, they don't even match well anyways as many of the R^2 values are small.

3) Similar to #2, I have a problem with your basic assumption about what the sensor is measuring (page 32, line 19). You are equating the ratio of blocked laser time to total time as proportional to particle mass. This is not correct. These two may correlate with each other (and this paper shows that sometimes it does, but mostly its a poor correlation), but these values are not linked by any physics. The ratio you use is representative of total particle number concentration, not mass. To get mass, you need information about the size of the particles, which the sensors provide in a very primitive way, but you don't seem to be using this information. The use of this assumption may entirely explain why the correlations are so poor some of the time, but there is just not enough information in this paper to properly assess this.

4) The emission factor calculation would be a promising method if it were done more rigorously. It seems like only 1 short time period was hand-picked from the entire dataset because the data looked right and happened to give a number that fell between published values that span 2 orders of magnitude. As other reviewers have pointed out, the uncertainty on this calculation seems way too low and is, in fact, missing for the reference analyzers. There needed to be alot more supporting measurements (i.e. wind speed and direction) available as well to ensure this calculation is valid. To be truly beneficial to the community, as promised on Page 12 lines 10-13, this calculation

needs to be proven to be valid on much shorter averaging time periods and for many more test cases.

Having seen several other reviewer comments already posted, I am in agreement with these other reviewers on most points and will not repeat all of the same comments already presented. The authors should very carefully respond to each of their concerns as well.

Specific comments

While generally written well enough to be understandable, the manuscript does need some careful attention to detail in a few spots.

The abstract is written to sound very promising; however, many of the R^2 values are too low to be considered a positive result/correlation.

Several references are missing from the bibliography, including "EPA, 2015" and "Sensiron, 2010".

Page 2, line 10 - Can you really cite people's "desires"?

p 2, l 19 - What are the advantages and disadvantages? Be more specific.

p 2, l 33 - "variety" is actually just 3 different models from the same manufacturer; this is a bit misleading.

p 3, l 12 - How are the sensors promising?

p 3, l 29 - Did you talk to the manufacturers to try to get more information? To properly assess an instrument's performance, we really need to have more information on its design.

p 3, l 30 - Are the results supposed to be linear or exponential? On page 6, line 5 you

state that it doesn't matter whether Deming or simple linear regression is used - so what does this mean about the errors of each measurement? On page 8, line 2 you mention how a 5^{th} order polynomial has no physical meaning, but does an exponential fit have a physical meaning? Just because this is the shape of the signal near saturation does not mean that there is real meaning in that measurement range.

p 4, l 24 - "should have provided" - Did it? Be more specific.

p 5, l 7 - "Therefore" is basically saying that because these sensors can vary by a large amount because of varying particle composition in the ambient atmosphere, you are going to ignore controlled laboratory experiments and instead focus on field performance of these sensors. This would be an okay focus of the study *IF* you had more measurements to compare to and made proper assumptions (see #3 above). Otherwise, you are trying to evaluate sensors in an environment that they are expected to be highly varied (because particle composition is highly varied) and you are not measuring this varied composition with any other supporting measurements.

p 5, l 15 - A HEPA filter does not ensure that the TEOM is functioning properly. Be more specific and precise with the wording.

p 6, l 2 - Is $R^2 = 0.1$ really "marginal" correlation?

p 6, l 22 - If the entire sampling period is used to "calibrate" the PPD20V sensor to the TEOM measurements, it should not be surprising then that the absolute values of mass concentration are close.

p 6, l 23 - What does "tracked the TEOM well" mean, especially in light of how your 'calibration' was done?

p 7, l 22 - How did these effects likely lead to large errors? Be more specific.

p 8, l 12 - Why aren't the intercepts zero? Zero mass concentration should be zero voltage on the sensors, correct?

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p 9, l 2-3 - I would say that the present study also shows that low-cost sensors do not perform well at US ambient concentrations.

p 11, l 9-10 - I do not understand this sentence.

Fig 5 - Is there a typo in the legends? The two PPD60PV curves look nothing like each other.

In general, more information could be given in each figure caption.

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