Effect of Controlling Dilution Air Quality On Different Emissions Measurements

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Introduction

In 2007 the U.S. Environmental Protection Agency reduced the heavy-duty Diesel on-road emissions standards for particulate matter (PM) to 0.01g/hp-hr The European Union has also passed similarly stringent emissions regulations. Accurately measuring and impartially sampling PM at low concentrations poses an engineering challenge. For example, adsorption of gaseous compounds to a PM filter may be a significant source of the total "PM" mass[1]. Gaseous compounds or particles found in the exhaust dilution air may also bias mass measurements. Objectives of this study are to physically and chemically characterize different methods of dilution air cleaning and to investigate the influence of dilution air quality on gravimetric filter artifacts

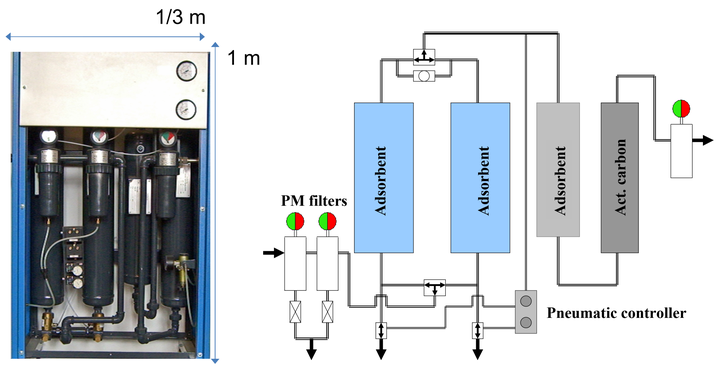
Dilution Air Cleaning

Some options exist for cleaning exhaust dilution air, most are specific to the emissions measurement method:

CVS (high-flow)
- HEPA* and/or carbon filters
- Few complete commercial systems are available
  - -Dilution Air Refinement (DAR, Horiba)
  - -Dilution Air Purification System (DAPS, Donaldson)

Partial flow sampling/2nd dilution of CVS flow (low-flow)
- Fixed-bed desiccant dryers*
- Pressure swing adsorption (PSA)*
- Catalysts, denuders and many others

*tested in this study

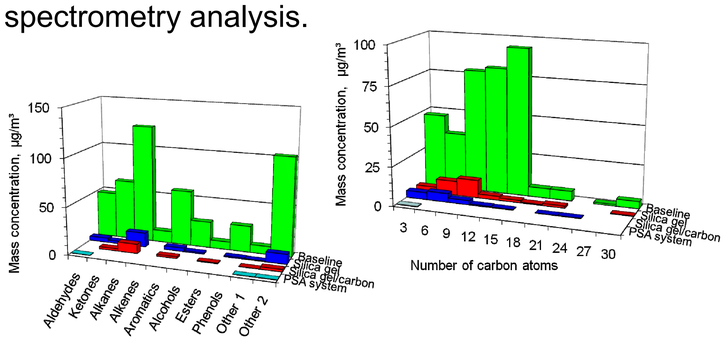


Photograph and schematic of a pressure swing adsorption system

Results — Dilution Air Cleaning

This work evaluated the filtration, drying and adsorption (VOC removal) performance of a silica gel dryer, silica gel/carbon dryer and PSA system. For VOC analysis, the systems were tested in parallel, each with an outlet flow rate of 200 slpm.

VOC removal: Gas samples were taken from the influent (baseline) and effluent of each air treatment system air using adsorption tubes followed with thermal desorption - gas chromatography - mass spectrometry analysis.

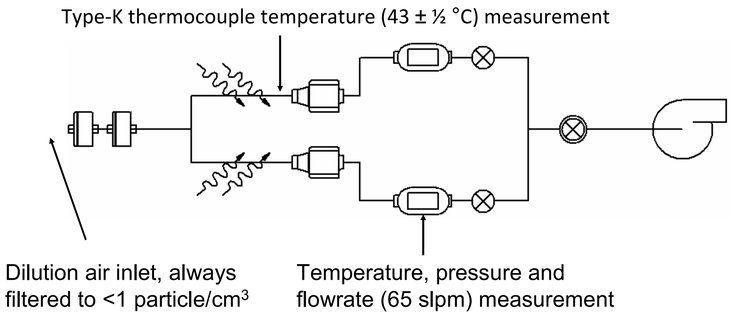


Summary: The dilution air cleaning evaluation is summarized below. Complete testing methodology details are available from Swanson, et. al[2]

		Baseline	Silica gel	Silica gel/carbon	PSA system
Particles part/cm³	Avg	8,890	8.2	5.1	0.6
	Sdom	740	0.1	1	0.2
Total VOCs ppbv	Avg	822	55	24	<1
	Stdev	122	43	21	<1
Humidity %RH	Avg	8-12	4	0.5	<0.01
	Breakthrough time	n/a	4hrs	4 hrs	n/a
NOx ppbv	Avg	14.6	n/a	n/a	<1
	Stdev	5.1	n/a	n/a	n/a

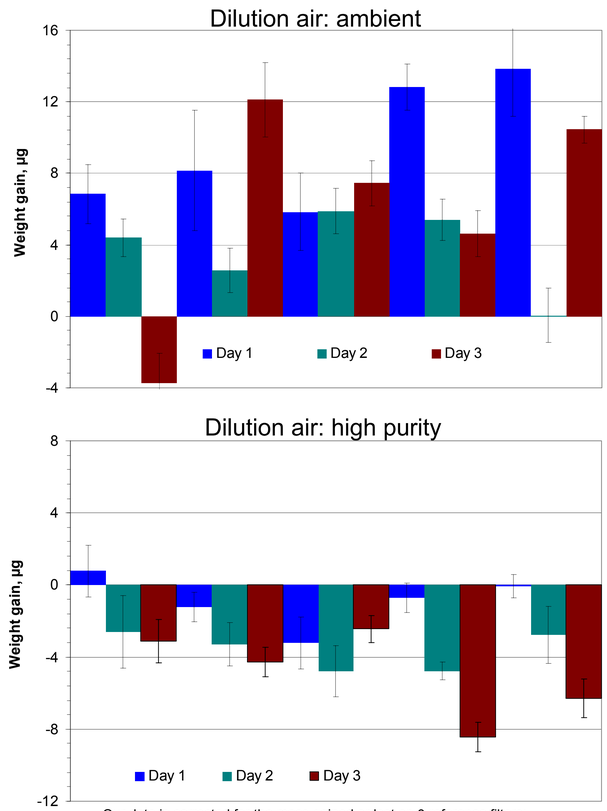
Filter Sampling

- We are evaluating filter artifacts that are attributable to gaseous compounds in the dilution air and testing representative levels of air purity
- To date, filtered ambient air and high-purity PSA air have been tested
- Our sampling methods and filter weighing align with 2007 USEPA regulations



Results — Dilution Air Artifacts

Dilution air filter artifacts were evaluated by sampling ~1.3 m³ of dilution air in 20 min, effectively simulating a US FTP certification test. The weight gained is due to adsorption of gas molecules on the TX40 filter. Each data set represents five filter samples, with each test done on a different day.



Our data is corrected for the mass gained or lost on 3 reference filters:

Ambient air samples	High purity air samples:
n/a µg (day 1)	-0.45 µg (day 1)
-0.44 µg (day 2)	-1.23 µg (day 2)
-1.07 µg (day 3)	-0.22 µg (day 3)

Conclusions

- The PSA process can generate 200 slpm of high-purity air (<1 ppbv VOCs, <1 part/cm³, <1ppbv NO_x)
- High purity dilution air reduced the average apparent gaseous filter artifact from 6.44 to -3.14 µg (~10% of US standard). Khalek[3] repeatedly found that during a HDD steady-state condition, filter mass loadings were 10 µg.
- These results suggest that the amount of PM emitted by modern Diesel engines may be much lower than indicated by filter measurements
- TX40 filters lose mass during handling or sampling
- Future work is determining the chemical identity of the compounds that adsorb to the filter, for "blank" samples and dilution air/exhaust mixtures

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References

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[2]Swanson, J. et. al. "An Alternative Method for Generating Ultra-Clean Dilution Air For Engine Emissions Measurements." SAE paper 2007-01-1111
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