# RATIONALE FOR PROGRAMMING A PHOTOMETER CALIBRATION FACTOR (PCF) OF 0.38 FOR AMBIENT MONITORING

APPLICATION NOTE EXPMN-007 (A4)

## Introduction

DustTrak™ II and DRX Aerosol Monitors are now available with two default calibration factors—Factory Default of 1.00, which is the calibration to Arizona Road Dust/ISO 12103 A1 Test Dust (a.k.a., SAE Fine Dust) and an ambient calibration factor of 0.38, which is appropriate for ambient/fugitive emissions monitoring applications. The ambient calibration factor of 0.38 was not chosen arbitrarily. This ambient calibration factor was selected based on published peer reviewed literature using either the DustTrak I/II/DRX monitor.

## Rationale

The rationale to use an ambient calibration factor of 0.38 was based primarily off of a Journal Paper titled "Validation of Continuous Particle Monitors for Personal, Indoor and Outdoor Exposures", Lance Wallace et. al. (2011) **21**, pages 49–64, published in the *Journal of Exposure Science and Environmental Epidemiology*.

This study was extensive with sample size of 799. Measurements were made indoors and outdoors. In this paper, a plot of Gravimetric Average $PM_{2.5}$ versus DustTrak Average $PM_{2.5}$ Concentrations provided the following relationship:

$$DustTrak\ Concentration,\ \frac{\mu g}{m^3} = 2.64\ x\ \ Gravimetric\ Concentration - 2.9$$

To determine the ambient calibration factor for the DustTrak monitor, the above equation needs to be re-written as shown below:

$$Gravimetric\ Concentration\ or\ Actual\ Concentration\ , \frac{\mu g}{m^3} = \frac{DustTrak\ Concentration}{2.64}$$

Therefore, for the DustTrak monitor to read actual concentrations, a new custom calibration factor needs to be programmed in to the instrument. DustTrak monitor ambient calibration factor based on the above equation would then be 1/slope, which is 1/(2.64) or = 0.38. An offset of 2.9 µg/m³ may be corrected by zeroing the DustTrak monitor at regular intervals either manually or using the Auto Zero Module, TSI P/N 801690.

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This data set was chosen simply because there is no other study that is as comprehensive as this, which included the following:

1. Indoor measurements and outdoor measurements
2. Personal and Area measurements
3. Summer and winter sampling
4. Study participants included adults and asthmatic kids
5. 4 different types of monitors (not just DustTrak monitor)
6. Additional measurement of air change rates, temperature and humidity
7. Study included the effect of humidity on instrument performance
8. Characterization of zero drift with time

Other studies have also independently come up with calibration factors for the DustTrak (I/II/DRX) aerosol monitor and in all cases, the DustTrak monitor is known to over-estimate the concentration of ambient aerosols. The Table below summarizes the calibration factors obtained by different investigators.

| Peer Reviewed Paper | Ratio of DustTrak Concentration over Reference Concentration | Calibration Factor | Aerosol |
|---|---|---|---|
| Branis and Hovorka (2005) | 2.34 | 0.43 | Ambient Air |
| | 2.12 | 0.47 | Ambient Air |
| | 3.91 | 0.26 | Ambient Air |
| | 3.29 | 0.30 | Ambient Air |
| | 4.02 | 0.25 | Ambient Air |
| | 3.37 | 0.30 | Ambient Air |
| | 3.12 | 0.32 | Ambient Air |
| | 2.49 | 0.40 | Ambient Air |
| | 3.20 | 0.31 | Ambient Air |
| | 1.27 | 0.79 | Ambient Air |
| | 1.93 | 0.52 | Ambient Air |
| McNamara et. al (2011) | 2.18 | 0.46 | Ambient Air |
| | 1.59 | 0.63 | Forest Fire |
| | 1.70 | 0.59 | Forest Fire |
| | 1.60 | 0.63 | Indoor Air |
| | 1.43 | 0.70 | Ambient Air |
| Yanosky et. al. (2002) | 2.20 | 0.45 | Ambient Air |
| | 2.60 | 0.38 | Ambient Air with Wood Smoke – $PM_{10}$ |
| Zhu et al. (2011) | 2.03 | 0.49 | Ambient Air |
| Kingham et al. (2006) | 2.73 | 0.37 | Ambient Air with TEOM |
| Heal et al. (2000) | 2.20 | 0.45 | Ambient Air - $PM_{10}$ |
| Chung et. al. (2001) | 3.00 | 0.33 | Ambient Air - $PM_{2.5}$ |
| Wallace et. al. (2011) | 2.64 | 0.38 | Ambient Air - $PM_{2.5}$ |
| Osman et. al. (2007) | 3.00 | 0.33 | Indoor $PM_{2.5}$ |

## Why do photometric instruments like the DustTrak Aerosol Monitor always over-estimate ambient aerosol concentrations?

Almost all peer reviewed publications confirm the over-estimation of concentration by photometric instruments like the DustTrak monitor for ambient aerosol measurements. This is due to the complex Mie-scattering optical properties for aerosols (i.e., density, refractive index, morphology, size, and size distribution). All models of DustTrak monitor are calibrated to A1 Test Dust that has a size distribution between 0.1 to 10 µm with particle density of 2.65 g/cc. On the other hand, ambient aerosols are complex mixtures (polydisperse aerosols) of crustal matter (densities >2 g/cc, but less than A1 Test Dust) and combustion aerosols from urban pollution sources (low density, about 1 g/cc). The average density of ambient aerosol is known to vary between 1.5 to 1.7 g/cc, which will result in over-estimation of the concentration by any photometer like a DustTrak monitor that is calibrated to A1 Test Dust. The over-estimation of concentration by the DustTrak monitor is also influenced by relative humidity. Relative humidity >70% can cause hygroscopic particles to grow (hydrate) in size leading to over-estimation of concentration, when compared to reference sampling methods like Federal Reference Method using a 40-mm filter, that typically dry off the water (humidity) by desiccating the filter over a period of 24 to 48 hours prior to determining the filter weight gravimetrically.

## Discussion

An ambient calibration factor of 0.38 approximates ambient concentration measurement for the DustTrak aerosol monitor which, is calibrated to A1 Test Dust. A1 Test Dust was originally selected as the ISO 12103 photometric calibration standard because it is fairly representative of a wide variety of windblown dusts, but not so for ambient measurement of urban pollution sources.

TSI recommends that the user perform custom calibration using a collocated reference method or the downstream 37-mm filter cassette provided with the DustTrak II/DRX Desktop instruments. For those who cannot perform this calibration, an ambient calibration factor of 0.38 would be closer to actual reference method concentrations (i.e., reference method sampling) than simply using the Factory Default Calibration factor of 1.00, to A1 Test Dust.

TSI also recommends that the user always run the DustTrak monitor with an Auto Zero Module for outdoor ambient monitoring applications. The Auto Zero Module can be programmed to run at any desired interval from as frequent as 15 minutes to every 12 hours. This depends on the rate of change in ambient temperature over time.

The advantages DustTrak monitor provides are: access to real time data; very low cost of ownership in terms of maintenance compared to reference and FEM samplers; low purchase price compared to reference and FEM samplers, ease of use compared to reference and FEM samplers, and portability and the ease with which custom calibrations can be performed for improved accuracy when compared to reference and FEM samplers. This allows DustTrak monitor to be cost effective and appropriate for low maintenance fugitive dust monitoring networks that run 24/7.

Ultimately, it is the end users decision whether or not to use the ambient calibration factor of 0.38, for ambient/fugitive emissions monitoring applications. TSI is simply providing the research information on another choice of calibration factor to use based on this comprehensive study and many others.

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