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Identification of technical problems affecting performance of DustTrak DRX aerosol monitors

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ABSTRACT

The TSI DustTrak Aerosol Monitor is a portable real-time instrument widely used for particulate matter (PM) mass concentrations monitoring. The aim of this work is to report on issues that have arisen from the use of the latest generation models DustTrak DRX (8533 and 8534) in the BREATHE, UPTECH and IMPROVE projects that can compromise data quality. The main issue we encountered was the occurrence of sudden artefact jumps in PM concentration, which can involve an increase from a few to some hundreds of $\mu\text{g}\cdot\text{m}^{-3}$. These artefact jumps can sometimes be easily recognised (“obvious jump”), while others can be difficult to identify because the difference in the concentrations before and after the jump might be just few $\mu\text{g}\cdot\text{m}^{-3}$ (“possible jump”) or because the jump is sustained over the whole monitoring period and only detectable if PM concentrations are simultaneously measured by other instruments (“hidden jump”). Moreover, in areas of relatively low PM levels, the unit reported concentration of 0 $\mu\text{g}\cdot\text{m}^{-3}$ for ambient PM concentration or even negative concentration values which may seriously compromise the dataset. These data suggest issues with the detection of low PM concentrations, which could be due to an incorrect instrument offset or the factory calibration setting being inadequate for these PM concentrations. The upward and downward artefact jumps were not related to especially dusty or clean conditions, since they have been observed in many kinds of environments: indoor and outdoor school environments, subway stations and in ambient urban background air. Therefore, PM concentration data obtained

with the TSI DustTrak DRX models should be handled with care and meticulously revised before being considered valid. To prevent these issues the use of auto zero module is recommended, so the DustTrak monitor is automatic re-zeroed without requiring the presence of any user.

KEYWORDS

Portable instrument, TSI DustTrak, performance, mass concentration, PM_x

1. INTRODUCTION

DustTrak Aerosol Monitors (TSI Incorporated, Shoreview, MN, USA) are a family of portable real-time instruments for the measurement at high temporal resolution of mass concentration of particulate matter (PM). All DustTrak models have in common that they are optical instruments that use a sheet of laser light formed from a laser diode and light-scattering by the cloud of particles detected in the chamber by a photo detector. The DRX series differs from other DustTrak models in that sense that it combines the photometric measurement of the group of particles in the measurement chamber with the optical sizing of single particles in one optical system (Wang et al., 2009), thus reporting concentrations for different size fractions. The DustTrak is a very practical, compact, relatively low-priced instrument, and the concentration range that it is able to measure makes it suitable for very different environments (from clean indoor or outdoor environments to dusty workplaces). It also offers a very precise, repeatable measurement in the sense that co-located instruments will report the same measurement value as long as the same calibration is used and all operational parameters are within tolerance (in particular flow rate and zero off-set). Their accuracy is impacted by the fact that every light-scattering measurement is sensitive to particle size distribution, shape and composition (including density) as scattering per unit mass is a strong function of particle size and refractive index (Hinds, 1999). This implies that the relationship between gravimetric mass and DustTrak measurements would not be consistent across environments affected by very different sources. For consistent biases, a statistical adjustment with an on-site photometric correction factor (PCF) obtained by comparison with the reference gravimetric measurements can be used to correct concentrations. This is actually recommended by the manufacturer as the factory calibration made with the standard ISO 12103–1, A1 test dust (“Arizona Road Dust”) is only representative for PM of very similar properties (TSI Inc., 2014). For this reason the Desktop DRX instrument (model 8533) is fitted with a 37-mm filter cassette in-line with the aerosol flow, allowing for a gravimetric analysis of the same aerosol as measured optically.

The first model of DustTrak (model 8520; Table 1) was released in the early 1990s and widely used for PM mass concentration measurements (He et al., 2004; MacNeill et al., 2012; Moosmüller et al., 2001; Wang et al., 2011; among others). Several publications tested the performance of the DustTrak 8520 against standard gravimetric methods and other light-scattering or real-time instruments. Results showed that this model was very consistent and with an excellent signal-to-noise ratio, but with a low accuracy compared to the reference method when using its factory calibration, generally resulting in 2-3 times higher

concentrations (Chung et al., 2001; Kim et al., 2004; Kingham et al., 2006; Moosmüller et al., 2001; Yanosky et al., 2002; Zhu et al., 2011). According to this, it was evident that for accurate results it is necessary to calibrate the DustTrak for the specific aerosol of the sampling area/environment under study. These findings established the DustTrak as a reliable instrument for on-line measurements of PM.

Table 1. Main features of the different models of DustTrak Aerosol Monitors (TSI).

	DustTrak 8520	DustTrak II 8530	DustTrak II 8532	DustTrak DRX 8533	DustTrak DRX 8534
Release year	(1991) Now discontinued	2008	2008	2008	2008
Type	Desktop	Desktop	Hand-held	Desktop	Hand-held
Sensor type	90° light-scattering, laser diode				
Aerosol concentration range (mg·m ⁻³)	0.001 - 100	0.001 - 400	0.001 - 150	0.001 - 150	0.001 - 150
Particle size range (µm)	Approx. 0.1 - 10	Approx. 0.1 - 10	Approx. 0.1 - 10	Approx. 0.1 - 15	Approx. 0.1 - 15
Simultaneous fractions measured?	No	No	No	Yes. PM ₁ , PM _{2.5} , Resp (PM ₄), PM ₁₀ , Total	Yes. PM ₁ , PM _{2.5} , Resp (PM ₄), PM ₁₀ , Total
Flow rate (l·min ⁻¹)	1.7	3.0 (set at factory) 1.4 - 3.0 adjustable	3.0 (set at factory) 1.4 - 3.0 adjustable	3.0	3.0
Other characteristics		Automatic re-zeroing; Heated inlet; Sample conditioner (accessories)		Automatic re-zeroing; Heated inlet; Sample conditioner (accessories)	

DustTrak II 8530 and 8532 models (desktop and hand-held instrument, respectively; Table 1) came to the market in 2008. Matti Maricq (2013) examined the performance of the DustTrak II 8530 against gravimetric methods. Their conclusions are in agreement with the performance of the previous DustTrak model 8520: the instrument provides accurate PM data that correlate well with standard gravimetric methods, but only when there is little variation of particle morphology and composition to the A1 test dust used for the factory calibration. Moreover, Holstius et al. (2014) observed consistently higher PM_{2.5} concentrations reported by DustTraks in comparison with β-attenuation measurements (BAM-1020, Met One Instruments) with a low coefficient of determination (R²=0.49). The R² was much higher when compared to GRIMM Optical Particle counter (OPC - Model 1.108, GRIMM) for PM₂ (R²=0.80) and for PM₃ (R²=0.77). Finally, contrary to what was found by Holstius et al. (2014), McNamara et al. (2011) reported a high correlation of DustTrak with BAM (r=0.9873) in a controlled laboratory with wood stove burns emissions. They also determined correction factors (as averaged DustTrak

concentrations/averaged concentrations from a reference instrument) for DustTrak which ranged from 1.43 to 2.18 in different environments affected by wood smoke when compared to different reference instruments.

The DRX versions of DustTrak are models 8533 and 8534 (desktop and hand-held, respectively, Table 1) which also become available in 2008. The novelty of these DRX models is their ability to measure mass concentration of different particle size fractions simultaneously (PM_{10} , $PM_{2.5}$, Respirable particles (PM_{4}), PM_{10} , Total particles). Their performance has been assumed to be as good as the previous models, as shown by the comparatively small number of studies focused on testing their performance. However, a recent publication by Viana et al. (2015), identified an anomalous behaviour during the use of DustTrak DRX units in the framework of the ERC BREATHE school study. The aim of this work is to report a number of issues identified in the performance of DustTrak DRX, which may significantly affect the quality of the data. Particularly, we refer to sudden increases in PM concentrations that do not reflect the actual concentrations (artefact jumps). Some of them are effortlessly identifiable (when the difference with the actual PM concentrations is very large, $> 100 \mu g \cdot m^{-3}$), while in other cases the jump may pass unnoticed (for relatively small differences). Moreover, long time-series of zero concentrations were also reported by some DustTrak units. This is of a high importance considering that this instrument is used for monitoring PM_x concentrations in numerous studies.

2. METHODOLOGY

2.1. Study areas and data sources

DustTraks were employed to assess PM concentrations in indoor and outdoor environments in schools in Barcelona (Spain), and Brisbane (Australia) within the BREATHE and UPTECH Projects and inside subway stations in Barcelona, Spain (IMPROVE Project), thus, covering a wide variety of expected concentrations, from clean to very dusty conditions. The instruments were employed with the factory Arizona Road Dust calibration.

- 1) The BREATHE Project (<http://www.creal.cat/projectebreathe>) was carried out in 39 schools located in Barcelona and in the surrounding city of Sant Cugat del Vallès. In each school, two DustTrak DRX units (model 8533) were placed simultaneously inside a classroom and in the playground to monitor PM_{10} , $PM_{2.5}$, Respirable (PM_{4}) and PM_{10} mass concentrations. Two different 1-week measurement campaigns were carried out at each school from January until June 2016 (campaign 1) and from September 2012 until February 2013 (campaign 2; further information on the fieldwork campaigns is available elsewhere; Rivas et al., 2014). Before starting sampling in each school, the zero calibration was performed with the Zero (HEPA) filter, as recommended by the manufacturer. If no issues were detected, the instrument monitored concentrations for 4 consecutive weekdays (from Monday morning until Friday morning; ~96 h) without performing the zeroing again. All the instruments were moved every week from one school to the next one. The time-base was set to 10 minutes. Four units of DustTrak 8533 (Table 2) were purchased specifically for the BREATHE project, and

therefore were calibrated just before starting the measurements. Moreover, during the gap between campaigns, the DustTraks were sent for factory maintenance and were calibrated again. Simultaneously (and positioned at about one meter distance from the DustTrak), PM_{2.5} gravimetric samples were obtained by means of an EU reference high volume sampler MCV CAV-A/mb (30 m³·h⁻¹) with an inlet with a specific nozzle plate for PM_{2.5} (MCV, Spain). PM_{2.5} was collected on Pallflex quartz fibre filters (PALL 2500 QAT-UP 150 mm) to obtain mass concentrations. The filter sampling was carried out only during school hours (9-17h, local time). Schools in Barcelona might be affected by very high concentrations of PM, especially in the case of those schools that have sandy playgrounds (Rivas et al., 2014).

- 2) As one of the components of the UPTECH Project, mass concentrations of ambient PM₁, PM_{2.5} and PM₁₀ were measured continuously for 2 consecutive weeks at a centrally located outdoor site within the school ground at 25 primary schools within the Brisbane Metropolitan Area, Australia. One school was monitored at a time (<https://www.qut.edu.au/research/research-projects/uptech>) between October 2010 and August 2012. A DustTrak 8534 was used for the monitoring, which was a new and recently calibrated unit (Table 2). When this unit required maintenance, it was substituted by a DustTrak 8533. The DustTrak underwent the manufacturer's recommended start-up preparations, such as the zero calibration prior to use at every new location, before starting the monitoring in each school and every 2 or 3 days during the 2 weeks of measurements. Data were collected every 30 seconds, but 10-minute averages were used in this work. In addition, PM_{2.5} was collected on filters from 08 to 17h (local time) for elemental/organic carbon (EC/OC) and for 24h for trace element analysis. Additional information on the UPTECH project is provided in Salimi et al. (2013). The weighted PM_{2.5} on these filters were used for the performance and quality checks of DustTrak data for the UPTECH project.
- 3) The IMPROVE project (<http://improve-life.eu>) focuses on air quality in the subway indoor environment (Martins et al., 2015). Within the project, PM concentrations in a subway platform in Barcelona were monitored with a DustTrak during two months from 20th January until 31st March 2015. A DustTrak DRX (model 8533; Table 2) was employed, which had been calibrated 1.5 years before the sampling campaign (August 2013). The time-base was set to 5 minutes, although hourly averaged data is presented in this work since the time series presented include a long period of time. A zero calibration was performed with the Zero (HEPA) filter, as recommended by the manufacturer, before starting the sampling. After observing any issues with the data, the zero calibration was performed on a weekly basis. PM_{2.5} samples were collected on quartz microfiber filters by means of a high volume sampler (HVS, Model CAV-A/MSb, MCV), programmed to sample daily over a 19 h period (from 5 a.m. to midnight, subway operating hours) at a sampling flow rate of m³·h⁻¹.

Table 2. Models of DustTraks used in the different studies included in this work.

Study	DustTrak DRX model
BREATHE	Mainly 8533, few cases 8534
UPTECH	Mainly 8534, sometimes 8533
IMPROVE	Model 8533

During the evaluation of the data obtained from these three studies, some issues put in question the quality of the data, which are summarised and discussed in the next section. The analyses were performed with the R statistical software (v 3.2.2., R Core Team, 2016) and the package *openair* (Carslaw and Ropkins, 2012).

3. RESULTS AND DISCUSSION

3.1. Artefact jumps in PM concentrations reported by DustTrak DRX

The range of the 8h-average PM_{2.5} concentrations (from gravimetric samples) in the BREATHE schools was wide, from 10 to 111 $\mu\text{g}\cdot\text{m}^{-3}$, as the schools were affected by the presence of sandy playgrounds (Rivas et al., 2014). Three time series corresponding to indoor and outdoor PM concentrations measured with DustTrak DRX (model 8533) in three different BREATHE schools are shown in Figures 1 and S1. These time series were selected as representative of different kind of artefact jumps in PM concentrations that were widely observed in the data obtained with DustTrak DRX devices during the two campaigns in the BREATHE schools. This kind of behaviour was also observed by Viana et al. (2015) in an intercomparison exercise between the DustTraks used in the BREATHE Project. The first artefact jump (Figure 1a) is an example of an “obvious jump”, that is, a jump which usually involves the sudden increase of $>50 \mu\text{g}\cdot\text{m}^{-3}$ above the actual PM concentrations (in fact, some jumps were up to 700-800 $\mu\text{g}\cdot\text{m}^{-3}$ above the actual PM concentrations, as can be observed in the correlation in Figure 2). In the case of this example, concentrations of outdoor PM (in all the three size fractions: PM₁, PM_{2.5} and PM₁₀) sharply increased $>150 \mu\text{g}\cdot\text{m}^{-3}$. After this sharp increase, concentrations kept at around 200 $\mu\text{g}\cdot\text{m}^{-3}$ until the fieldworker arrived the next day and performed a new zero calibration. Once the unit started running again, concentrations went down to similar levels as those observed before the jump, which emphasizes the importance of the zero calibration. This type of jump was more often observed in DustTraks that were monitoring outdoor air in comparison to indoor air during the BREATHE measurements. Contrary to the “obvious jumps”, Figure 1b is an example of a “possible jump” which are difficult (or even impossible) to identify since the difference in concentration before and after the possible jump might be relatively small and not be sustained over time and therefore confused with a real peak in concentration. On the other hand, it could also happen that the artefact jump in the concentration is sustained over the whole measuring period, as shown in Figure 1c. In this case, outdoor PM concentrations (of all fractions) were around 50 $\mu\text{g}\cdot\text{m}^{-3}$ during the whole period (average PM_{2.5} = 55.7 $\mu\text{g}\cdot\text{m}^{-3}$). These concentrations are quite high for Barcelona city and, moreover, indoor concentrations during night (when there are no indoor or outdoor activities/sources in the school) were much lower. However, one might consider these concentrations as the real ones that can be reached in schools due to high resuspension during

children activities. These “hidden jumps” can only be detected when PM concentrations reported by DustTrak are compared to concentrations from other colocated online instruments or gravimetric samples. In the case of Figure 1c, outdoor PM_{2.5} concentrations for the school time period (9-17h) were 55.9 $\mu\text{g}\cdot\text{m}^{-3}$ according to DustTrak while from gravimetric samples it was 22.6 $\mu\text{g}\cdot\text{m}^{-3}$ (for indoor, 26.2 and 24.6 $\mu\text{g}\cdot\text{m}^{-3}$, respectively). The disparity of the concentration differences reported by the gravimetric and the DustTrak in the indoor and outdoor environment might be explained by the different optical properties of the actual aerosol measured in each environment. This may lead to a one fold difference between the gravimetric results and those reported by the DustTrak in the outdoor environment while having similar concentrations indoors. However, since we observed in a number of cases this factor to change widely in different days for the same school classroom/playground, the variability could more likely be due to undetected “possible jumps”.

Figure 1. Time series of indoor and outdoor PM from schools (data from the BREATHE Project) showing the different artefact concentration jumps observed in the outdoor environment (blue line) for DustTrak DRX 8533: a) “obvious jump”; b) “possible jump”; c) “hidden jump” (real concentrations might be close to the lower part of the yellow area, according to gravimetric samples). Darker background area indicates concentrations $>150 \mu\text{g}\cdot\text{m}^{-3}$ (outside the range of DustTrak DRX), but were kept to illustrate the jumps.

“Obvious jumps” in PM concentrations that took place some time after the sampling commenced might be easy to detect and to correct by subtracting the difference, since after the jump, the data seems to be consistent, as indicated by Viana et al. (2015). However, the

main difficulty here lies in the identification of a possible or hidden artefact jump. Obvious artefact jumps are easily identified when correlating the PM data obtained simultaneously by DustTraks and by filter samples in the BREATHE schools (Figure 2; refer to Figure S2 for the scatterplots of each of the four instruments employed in the BREATHE campaigns). However, even after removing those specific artefact jumps from the linear regression, the R^2 between these two variables is still low considering that we are measuring the same parameter. The dispersion of the data is explained by the presence of relatively small artefact jumps which may take place in both directions: upwards and downwards.

Figure 2. Correlation between 8h $PM_{2.5}$ concentrations obtained by gravimetric samples ($PM_{2.5_FILTER}$) and by the corresponding averaged $PM_{2.5}$ concentration measured by DustTrak ($PM_{2.5_DST}$) during the BREATHE campaigns. Left panel includes all the data, while the right one is after excluding $PM_{2.5}$ concentrations from DustTrak above $200 \mu g \cdot m^{-3}$ (which are “obvious jumps”, clearly outliers affecting the correlation). Darker background area indicates concentrations $> 150 \mu g \cdot m^{-3}$ (outside the range of DustTrak DRX), but were kept to illustrate the jumps.

The artefact jumps were not specific of indoor and outdoor school environments. They have also been found in individual instruments in the urban background ambient air during a BREATHE’s intercomparison exercise using 5 collocated instruments, as well as several times on the subway platforms during the IMPROVE project. Figure 3 is an example of an “obvious artefact jump” that occurred after 6 weeks of measurements on a subway platform. After the jump, PM concentrations were maintained at about $70 \mu g \cdot m^{-3}$ of $PM_{2.5}$ higher (average $PM_{2.5}$ before of the jump = $48.5 \mu g \cdot m^{-3}$; after the jump = $115.5 \mu g \cdot m^{-3}$) during the final 4 weeks of sampling. In fact, two different correlations can be obtained, one for the period previous to the jump and another after the jump where the intercept increases from 3.3 to $72 \mu g \cdot m^{-3}$, respectively (the slopes change as well, from 1.20 to 1.03 ; Figure S3). Therefore, these jumps occurred in different kinds of environments with varying PM concentrations and composition

and they did not seem to be related to any environmental factors identified so far by the authors (such as high temperature, humidity, vibrations, etc.). In fact, in the intercomparison exercise reported in Viana et al. (2015) one of the 4 DustTrak monitors underwent a “jump” while the other 3 continued reporting similar concentrations. The manufacturer’s conjecture was that the DustTrak may receive and then maintain an incorrect zero offset. This offset is intended to compensate for the influence of ambient light or wall scattering in the measurement chamber and is subtracted from the measured signal to calculate the final PM concentration. Since the zero offset is a constant value, subsequent data correction is still possible. Performing the zero calibrations very often (e.g. on a daily basis), might help to avoid the occurrence of the jumps. However, as shown in the examples of this study it does not totally prevent the incorrect zero offsets or jumps. Further, it would not have been practical, or even possible to conduct very frequent zero calibration (every few hours), as this would require research personnel to be present during the monitoring, or travel to the site and back. The good news is that in order to make frequent zero check possible, the manufacturer developed for the newer models of the instrument an auto zero check module so the DustTrak monitor is automatic re-zeroed during long sampling periods without any user interference necessary. We do not recommend the use of DustTrak for long-term measurements without frequent manual zeroing (at least daily) or the use of the auto zero module. We also observed that the time elapsed from the last certified factory calibration might not be a decisive factor in the prevention or the occurrence of the artefact jumps, since the jumps were observed in DustTraks that were just calibrated and in those which calibration took place 1.5 years before the sampling campaign

Figure 3. Time series including an “obvious jump” in PM concentrations measured with a DustTrak DRX 8533 on a subway platform in Barcelona (IMPROVE). Darker background area indicates concentrations $>150 \mu\text{g}\cdot\text{m}^{-3}$ (outside the range of Dustrak DRX), but were kept to illustrate the jumps.

3.2. Negative and 0 values reported by DustTrak DRX under low PM concentrations

During the UPTECH project conducted in Brisbane schools, totally different performance issues were observed for the measured ambient PM mass concentrations at all schools using DustTraks. Figure 4 shows measured time series of ambient PM concentrations at one of the UPTECH schools. In this specific school, 71% of the data from the DustTrak (model DRX 8534) showed a 0 $\mu\text{g}\cdot\text{m}^{-3}$ $\text{PM}_{2.5}$ concentration (72% for PM_1 and 59% for PM_{10}). The average of 4 simultaneous $\text{PM}_{2.5}$ filter samples (24h) collected during this period showed an average of 17.2 $\mu\text{g}\cdot\text{m}^{-3}$, while the corresponding $\text{PM}_{2.5}$ average from DustTrak measurements was 0.9 $\mu\text{g}\cdot\text{m}^{-3}$ for the same period; thus, indicating a clear underestimation of PM concentrations. The PM_{10} and $\text{PM}_{2.5}$ concentrations reported for the same period by the Department of Environment and Heritage Protection (<https://www.ehp.qld.gov.au/air/data/search.php>) for the South Brisbane station were 16.6 $\mu\text{g}\cdot\text{m}^{-3}$ and 9.7 $\mu\text{g}\cdot\text{m}^{-3}$, respectively. The hourly-averaged range of $\text{PM}_{2.5}$ concentrations in the South Brisbane station was between 3.1 and 15.3 $\mu\text{g}\cdot\text{m}^{-3}$, which is within the concentration range that DustTraks should be able to measure. However, these issues suggest that the unit was not able to accurately report relatively low PM concentrations, which could be due to the factory calibration setting used for the local ambient PM concentration.

Figure 4. Time series of ambient PM concentrations measured by a DustTrak DRX 8534 at a school in Brisbane (data from the UPTECH Project) and distribution of the data.

An example from another UPTECH school is shown in Figure S4, where 0 or negative values were recorded by the DustTrak (model DRX 8534) in more than 50% of the PM_1 data and more than 25% of the $\text{PM}_{2.5}$. These two examples were not isolates cases. Actually, from the 22 UPTECH schools with PM data available, 11 schools showed a 25th percentile for $\text{PM}_{2.5}$ equal to 0 $\mu\text{g}\cdot\text{m}^{-3}$. From these, 4 schools also had the 50 percentile (half of the data) for $\text{PM}_{2.5}$ concentrations being 0 $\mu\text{g}\cdot\text{m}^{-3}$ (Table S1).

This kind of behaviour of the DustTrak DRX was observed (only once) in a BREATHE school in Barcelona. In this case (Figure S5), after 1.5 days showing 0 $\mu\text{g}\cdot\text{m}^{-3}$ of the PM_{10} , $\text{PM}_{2.5}$ and PM_1

fractions, the zero check was performed again. Afterwards, the minimum concentration observed was $16 \mu\text{g}\cdot\text{m}^{-3}$ for PM_1 and $\text{PM}_{2.5}$, and 18 for PM_{10} . Therefore, in this particular case the lower concentrations at the beginning of the sampling period seem to be affected by a downward jump.

3.3. Data correction and losses

The difficulty of identifying the artefact jumps can in some cases be overcome, and it might be possible to correct the data by subtracting or adding the PM concentration that correspond to the jump. This procedure will allow to re-level the concentration measurements recorded after the jump. This methodology is only possible if the variability of the concentration measurements is maintained after the jump, which could be a likely scenario. However, the identification and quantification of the jump is in itself a complicated task and this correction process will add further uncertainties to the data. Unfortunately, no correction can be applied to measurements of $0 \mu\text{g}\cdot\text{m}^{-3}$ and the data should be disregarded. The later scenario can particularly jeopardise a study, since most of the data might not be available and unable to be corrected.

Therefore, the raised issues that affect the newer DustTrak models do compromise the quality and availability of the data and should be revised carefully.

4. CONCLUSIONS

DustTrak DRX models 8533 and 8534 (desktop and hand-held, respectively) measure mass concentration of different PM fractions simultaneously (PM_1 , $\text{PM}_{2.5}$, Respirable particle (PM_4), PM_{10} , Total particles). In this work, we present unexpected behaviours of the DustTrak observed in PM data from the new generation of the DustTrak models (DRX), which became commercially available in 2008. Frequent artefact jumps in the time-series of PM concentrations have been observed, some of them being very easy to identify ("obvious jumps") while others may pass unnoticed ("possible" and "hidden jumps"). The artefact jumps in concentration have been seen while the DustTraks DRX were measuring in different environments: indoor and outdoor spaces in schools, subway platforms and in the ambient air of urban background station, without an explanation of their origin. Often zero offset calibrations may help to prevent the jumps. Moreover, long time-series of zero concentrations for all the size fractions of PM were recorded by the DustTrak DRX models for the ambient air in schools across the Brisbane Metropolitan Area, Australia. These issues significantly compromise the quality of the measured data. A possible downward artefact jump that caused the occurrence of negative concentration values were also observed in the collected data in Brisbane. Thus, PM concentration data obtained with the newer DustTrak DRX version should be handled with care and meticulously revised before being considered valid. Besides, downward jumps or measurements during low concentrations of PM that lead to $0 \mu\text{g}\cdot\text{m}^{-3}$ readings may seriously affect the study dataset.

Therefore, PM concentration measurements with the newer DustTrak DRX version should be done with care and data meticulously revised before being considered valid. We do not recommend the use of DustTrak for long-term measurements if calibrations of the zero offset are not performed regularly to identify and remove any abnormal “jumps” early. The use of the more recently introduced auto zero module is recommended, so the DustTrak monitor is automatic re-zeroed during long sampling periods without requiring the presence of any user.

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Identification of technical problems affecting performance of DustTrak DRX aerosol monitors

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SUPPLEMENTARY MATERIAL

Table S1. Minimum and 5, 10, 15, 20, 25 and 50th percentile of PM_{2.5} concentrations from the UPTECH schools.

School ID	DustTrak model	PM _{2.5} (µg·m ⁻³)						
		Minimum	Percentile					
			5 th	10 th	15 th	20 th	25 th	50 th
S01	DRX 8534	-11	-1	0	0	0	0	2
S02	DRX 8534	0	0	1	1	1	1	2
S03	DRX 8534	-3	-1	0	0	0	0	2
S04	DRX 8534	-19	-2	0	0	1	1	2
S06	DRX 8534	0	2	2	3	3	4	5
S09	DRX 8534	0	0	0	0	0	0	1
S10	DRX 8534	0	2	3	5	6	7	13
S11	DRX 8534	0	0	0	0	0	1	7
S12	DRX 8534	0	0	0	0	0	0	1
S13	DRX 8534	0	0	0	0	0	0	0
S14	DRX 8534	0	0	0	0	0	0	0
S15	DRX 8534	0	0	0	1	1	2	3
S16	DRX 8534	0	0	0	0	0	0	3
S17	DRX 8534	0	0	0	1	1	1	4
S18	DRX 8533	0	0	1	1	1	1	1
S19	II 8530 DRX 8533	0	0	0	0	1	1	1
S20	DRX 8534	0	0	0	0	0	0	0
S21	DRX 8534	0	0	0	0	0	0	1
S22	DRX 8533 DRX 8534	0	0	0	0	0	0	1
S23	DRX 8534	0	0	0	0	0	0	0
S24	DRX 8533	0	0	0	0	0	1	2
S25	DRX 8533	0	0	1	1	1	1	3
# schools with ≤0 µg·m ⁻³ :		22	20	17	15	13	11	4

Figure S1. Time series of indoor and outdoor PM from schools (data from the BREATHE Project) showing the different artefact concentration jumps observed in the outdoor environment: a) “obvious jump”; b) “possible jump”; c) “hidden jump” (real concentrations might be close to the lower part of the yellow area, according to gravimetric samples). Darker background area indicates concentrations $>150 \mu\text{g}\cdot\text{m}^{-3}$ (outside the range of DustTrak DRX), but were kept to illustrate the jumps

Figure S2. Correlation between PM_{2.5} concentrations obtained by gravimetric samples (PM_{2.5}_FILTER) and by the corresponding averaged PM_{2.5} concentration measured by DustTrak (PM_{2.5}_DST) for each of the DustTraks used in the BREATHE Project. For DST1 and DST3, PM_{2.5} concentrations above 200 $\mu\text{g}\cdot\text{m}^{-3}$ (artefact jumps) have been excluded. Darker background area indicates concentrations >150 $\mu\text{g}\cdot\text{m}^{-3}$ (outside the range of DustTrak DRX).

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486 **Figure S3.** Correlation between PM_{2.5} concentrations obtained by gravimetric samples (PM_{2.5}
487 Filter) and by the corresponding averaged PM_{2.5} concentration measured by DustTrak during
488 the IMPROVE measurements in the subway platform. Darker background area indicates
489 concentrations >150 µg·m⁻³ (outside the range of Dustrak DRX), but were kept to illustrate the
490 jumps.

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Figure S4. Ambient PM concentrations measured by a DustTrak DRX 8534 in a school in Brisbane (data from the UPTECH Project) and distribution of the data. Negative values of concentration can be observed in the three fractions shown.

Figure S5. Time series of indoor and outdoor PM from a school (data from the BREATHE Project) with indoor concentrations showing 0 $\mu\text{g}\cdot\text{m}^{-3}$ during long periods.