DUSTTRAK™ DRX AEROSOL MONITOR IN ENVIRONMENTAL APPLICATIONS

APPLICATION NOTE EXPMN-006

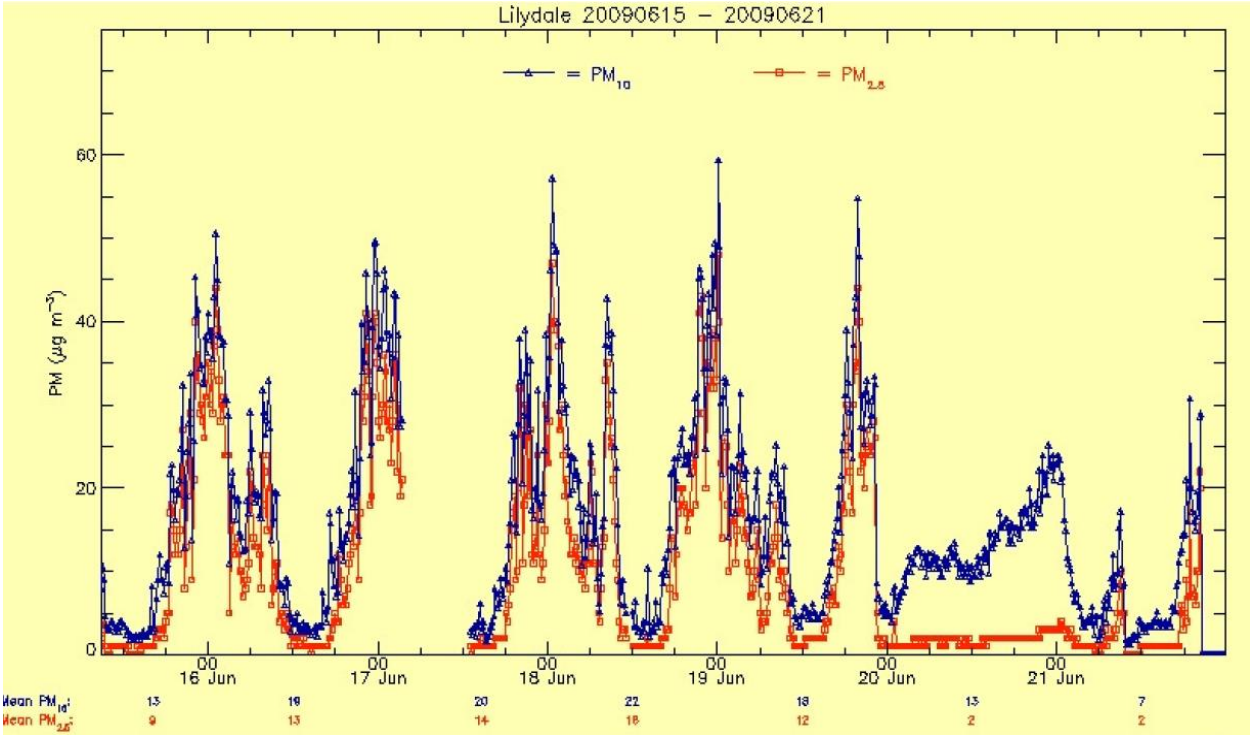
This document gives a brief overview over recent publications involving the TSI DUSTTRAK™ DRX monitor in environmental applications. References can be found at the end of the document.

Environmental Monitoring Network in Tasmania, Australia

The Tasmanian EPA has established a network of air monitoring sites called BLANkET - the Base-Line Air Network of EPA Tasmania.[1] The webpage states: "BLANkET is an EPA initiative that will increase the spatial coverage of air quality measurements in Tasmania, in particular (but not exclusively) for the monitoring of population exposure to smoke produced by planned burns. The network will consist of around 16 new air quality stations distributed around the state reporting real-time data to these web pages."

Each station is equipped with a TSI Model 8533 DUSTTRAK DRX monitor, a Davis Vantage Pro2 weather station, and a Cybertec Series 1000 3G modem for data transfer. The requirements for the instruments included low cost, small in size, low power consumption, and operation with minimal human intervention. The real-time data capability was an added benefit.

The main particle sources on Tasmania are wood combustion (seasonal prescribed burns, wild fires, residential heating)[1], sea salt and dust. Previous observations showed that wood combustion particles are typically much smaller than sea salt or dust particles, and track quite well with $PM_{2.5}$ measurements, whereas dust and sea salt match PM_{10}. Therefore, the capability of the DRX to measure both size ranges simultaneously was very important in this application. The graph below shows several days of data from the first monitoring station in Lilydale in June 2009.[2] From the start through June 19, $PM_{2.5}$ and PM_{10} are very well correlated, and almost identical. This indicates that the majority of the aerosol mass is below 2.5 µm, which is thought to indicate smoke in this environment. On June 20, on the other hand, $PM_{2.5}$ is very low, whereas PM_{10} goes up to about 20 µg m^{-3}. This event was dominated by particles larger than 2.5 µm, surmised to be dust and/or sea salt.



One issue that is discussed in the first report form Blanket is the problem of high humidity. High humidity can lead to water condensation, which in turn leads to a high reading in the DRX. To alleviate this problem, heated inlets were installed in the enclosures for the sampling stations. In some cases, readings were still high during times of elevated humidity, even when using the new inlet systems. The current understanding is that the air contained a lot of sea salt during this event, and the humidity allowed the particles to grow faster and larger, so a higher concentration of PM_{10} was measured.[3] Another approach would be to correct the data using a humidity correction presented by Laulainen[4] in 1993 and applied to the DustTrak by Ramachandran[5] in 2003.

$$Humidity\ Correction\ Factor = 1 + 0.25\frac{RH^2}{(1-RH)}$$

In addition to the fixed stations, a number of surveys were taken with a DRX in a car several times to investigate suspected instrument problems. The first station that was installed was expected to measure high $PM_{2.5}$ values during winter due to local sources (heating). Typically, however, the readings were very low, <6 µg m^{-3} for a daily average during July 2009[6]. Local investigations found that a light breeze from an unexpected direction delivered clean air right to the measurement station. Measurements taken at the same time with a DRX in a car inside the town found concentrations up to 50 µg m^{-3}. The fixed station consistently reported the lowest values of the points measured within the town.

Exposure to Particulate Matter in Traffic

Int Panis et al.[7] compared the dose of inhaled and retained particles for bicyclists and car passengers in three cities in Belgium. Particle concentrations were measured for particle number concentrations (PNC), using a TSI Model 8525 P-TRAK® counter, and $PM_{2.5}$ and PM_{10} using a TSI Model 8534 DUSTTRAK™ DRX monitor. A portable cardiopulmonary indirect breath-by-breath calorimetry system (MetaMax 3B) was used to measure breathing frequency, tidal volume and oxygen uptake. The TSI instruments were chosen for their time resolution, small size, battery operation, and, in case of the DRX, for the capability of measuring both $PM_{2.5}$ and PM_{10} simultaneously.

The authors found that bicyclists are taking up a higher dose of particles than car passengers, mostly due to three reasons:

1) Increase in breathing frequency and tidal volume: On average, the breathing frequency while bicycling was 1.6 times higher than while riding in a car. Tidal volume (average volume per breath) also increased by a factor of 2.6 to 2.8. The combination of these two effects results in an increase in minute ventilation (volume of air inhaled per unit time) by a factor of ~4.5. Obviously, increased breathing leads to a larger exposure to particulates in the air.
2) The deposition factor (DF), a measure of the fraction of inhaled particles deposited in the lung, increases strongly with increasing tidal volume. Combined with the increased inhaled volume, this significantly increases the number and mass of particles deposited in the lung.
3) Often, exposure time is longer when bicycling compared to driving a car. This effect is much smaller than the first two reasons noted, but is still significant.

Overall, the doses found for the three cities are as follows:

City	Mode of transport	PNC	µg PM_{10}	µg $PM_{2.5}$
		#dose m^{-1}	dose km^{-1}	dose km^{-1}
Brussels	Bike	4.6×10^6	2.6	0.8
	Car	9.0×10^5	0.4	0.1
Louvain	Bike	1.7×10^6	1.9	0.9
	Car	2.0×10^5	0.2	0.1
Mol	Bike	9.4×10^5	1.9	1.2
	Car	1.4×10^5	0.3	0.1

Some of the results found were not consistent, especially the ratio of particle number concentration and PM between car and bike measurements (see below). In two of the three cities (Brussels and Louvain-la-neuve), the PNC values measured in the car passenger compartment and during the bike ride are very similar. In the third city, Mol, the PNC was much higher in the car than during the bike ride. On the other hand, PM_{10} concentrations were higher for the bike rides in Brussels and Louvain-la-neuve, but very similar in Mol. The authors offer no good explanation for this, but differences in particle size could be the underlying cause.

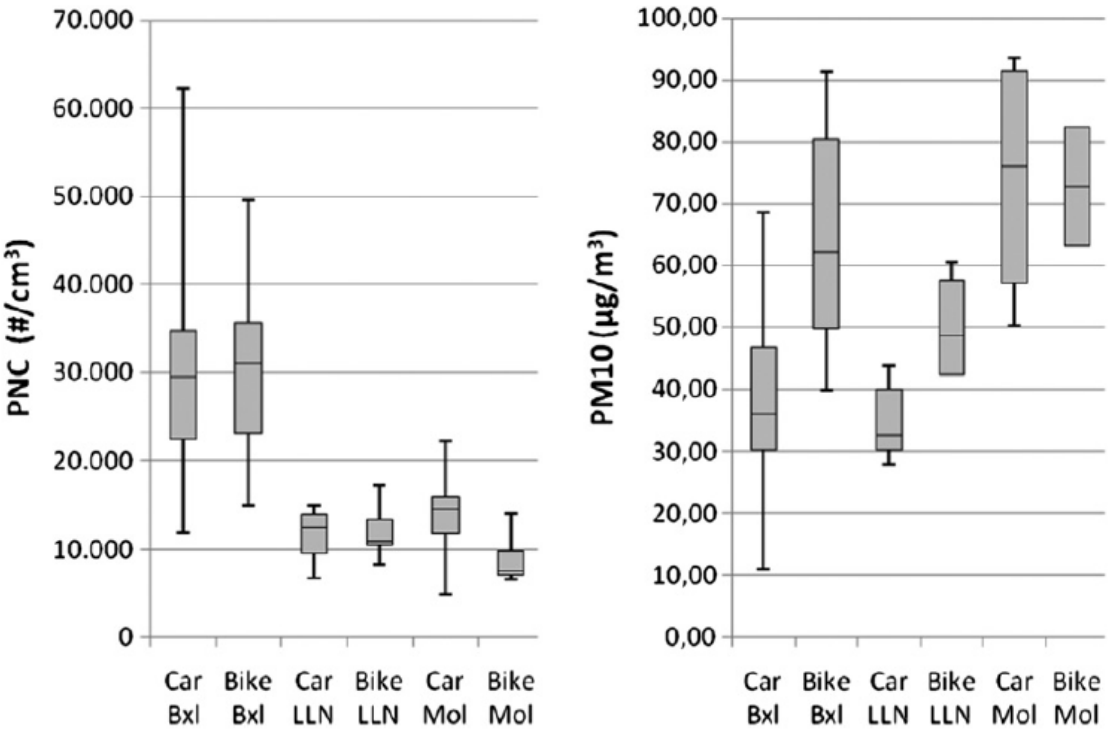


Fig. 3. Median, quartiles and range of PNC (left, #/cm^3) and PM10 measurements (right, µg m^{-3}).

The authors mention that instrument limitations for the P-TRAK® counter (20 nm cutoff, 5 x 10^5 cm^{-3} maximum concentration) make it difficult to accurately measure freshly emitted nucleation mode particles. For similar studies where portable CPCs are important, a CPC 3007 (10 nm cutoff, 10^5 cm^{-3} maximum concentration) is sometimes used[8, 9].

Exposure to Particulate Matter in Pizzerias

Buonanno et al.[10] report on investigations they did on air quality in pizzerias in Italy. They measured particle number concentrations, surface area, size distributions and PM_1, $PM_{2.5}$ and PM_{10} in 15 pizzerias in central Italy. Instruments used were a TSI Model 3936 SMPS™ system (number concentration, size distribution, surface area), a TSI Model 3321 APS™ spectrometer (number concentration, size distribution, surface area), a TSI Model 3550 NSAM (deposited surface area), a TSI Model 3775 CPC (number concentration), and a TSI Model 8534 DUSTTRAK™ DRX monitor (PM_1, $PM_{2.5}$ and PM_{10}). In each pizzeria, a background was established by measuring for 2 hours before wood stoves were lit. After the fire was started, another 2 hours passed before cooking was commenced.

All pizzerias in this study have a wood-fired oven in the dining area, where pizzas are cooked. The oven is heated to almost 500°C at the cooking surface, and pizzas are cooked for only about 90 seconds. The oven has an opening through which pizzas are inserted and removed from the oven.

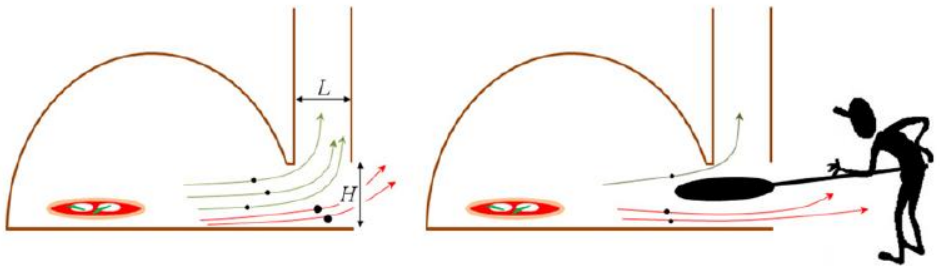


Fig. 1. Sketch of the fluid dynamic interaction between the wood oven and the hood a) without and b) with the presence of the *pizzaiolo*.

Particle number concentrations measured in the center of the dining area ranged from 2.5 x 10^4 to 6.4 x 10^5 cm^{-3}, with the background concentrations 3 – 74 times lower. The highest particle concentrations were found in the smaller pizzerias, with the highest value in an establishment with poor ventilation. Surface area concentrations ranged from 6.8 x 10^2 to 1.9 x 10^4 μm^2 cm^{-3}, with the highest values again in the same locations. As a comparison, surface area concentrations measured along a freeway in Los Angeles were ~150 μm^2 cm^{-3}. PM concentrations were also pretty high, with values form 10–327 μg m^{-3} for PM_1, 12-368 μg m^{-3} for $PM_{2.5}$ and 15-482 μg m^{-3} for PM_{10}. Ratios of the peak PM values to background values vary within the different pizzerias, giving an indication of different size distributions emitted from the different pizza ovens.

The authors also investigated surface area and mass deposited in the tracheobronchial (TB) and alveolar (A) regions of the lung. The range of values measured can be found below.

	Lung Deposited Surface Area (μm^2 cm^{-3})	Lung Deposited PM_1 (μg m^{-3})
TB	14 – 560	0.29 – 11
A	110 – 2900	1.7 – 59

These values are similar to concentrations found in ambient measurements in Minneapolis, MN and East St. Louis, IL[11].

Investigation of temporal the development of particle concentrations revealed increases in particle number and surface area shortly after lighting the wood fire in the ovens, whereas PM and deposited surface area only increased significantly after cooking of pizzas started. By comparing the temporal trend of PM_1/PM_{10} and $PM_{2.5}/PM_{10}$ ratios, the authors found a fast and simple way to determine a rough size distribution: Most of the PM emitted in pizzerias is due to submicrometer particles. In one pizzeria, PM_1 contributed 70% to the PM_{10} values.

Spatial Variation of PM10 near Major Roadways

Buurman et al. [12] investigated the change in PM_{10} concentrations with increasing distance from major roadways in Münster, Germany. They took measurements every 50 m up to a total distance of 300 m, using a TSI Model 8534 DUSTTRAK™ DRX monitor. They did not find any significant changes in PM_{10} with increasing distance. The only identified factor that had a significant influence on PM_{10} concentrations was wind direction. The authors mention that it would be interesting to increase the distance for measurements above 300 m, but in urban environments it is difficult to make sure no other source influences the measurements at these distances. This research supplements a body of research documenting a large degree of change in ultra-fine particle number concentration with increasing distance to a roadway[13-17].

Exposure to Crystalline Silica in Queensland, Australia

Hedges et al. [18] investigate exposure of quarry workers in Queensland, Australia to respirable crystalline silica (RCS). Exposure to RCS is controlled, as RCS is suspected of causing silica lung disease. A limit of 0.1 mg m^{-3} is in effect in Australia. Personal samples were collected using PVC filters and sampling pumps. In addition to the exposure measurements, the effectiveness of an air cleaning device for the cabins of machinery was tested, using TSI Model 8533 DUSTTRAK™ DRX monitor and TSI Model AM510 SIDEPAK™ pump.

A weak correlation between RCS concentration and total lung capacity was found. However, a majority of the observed workers were or had been smokers. Furthermore, most workers did not use Respiratory Protective Equipment (RPE), even though required, due to comfort issues.

The effectiveness of RESPA air cleaning devices for vehicles was tested by measuring PM levels before and after installation of the RESPA device, which consists of a pre-cleaner and a HEPA filter and provides a positive pressure in the vehicle cabins. Installation of the RESPA device typically lowered the cabin concentration by a factor of 2 – 12, often dropping the concentration below the limit requiring the use of RPE. This reduction was observed for all size fractions (PM_1, $PM_{2.5}$, PM_4, PM_{10}, TSP). In addition, a reduction in intensity of short term spikes in PM concentrations was observed as well, using the high time resolution of the DRX.

Conclusion

The TSI DUSTTRAK™ DRX monitor has successfully been used in a number of ambient applications, ranging from exposure measurements, both for commuters and for restaurant patrons, to a long-term monitoring network in Tasmania. The TSI DUSTTRAK™ DRX monitor offers a number of attractive features, among them the relatively low cost, portability, real-time data capability, and the concurrent measurement of PM_1, $PM_{2.5}$, PM_4, PM_{10} and TSP. These select applications show the usefulness of the DUSTTRAK™ DRX monitor in fields where real-time data and concurrent measurement of several PM fractions are of importance.

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USA	**Tel:** +1 800 874 2811	**India**	**Tel:** +91 80 67877200
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