



CHANGE

14 Stonehurst Drive
Queensbury, NY
12804

Consulting for Health, Air, Nature, & a Greener Environment

CHANGE-Dorchester Environmental Health Coalition Ultrafine Particle Ambient Air Quality Assessment in Dorchester, MA

Final Report

Prepared by:

Timothy R McAuley, MS, PhD
President and Founder, **CHANGE**

October, 2010

I. Introduction

Ultrafine particles (UFP) have attracted considerable attention as a potential health concern. Although epidemiological evidence links increases in particulate matter (PM) to increases in mortality and morbidity (Vedal, 1997; Dockery, 1993), further investigation is still needed to assess whether it is the mass (Osunsanya et al., 2001), number concentration (Peters et al., 1999; Yue et al., 2007), and/or other particle characteristics (e.g., surface area, and composition) that are associated with the adverse health effects of exposure to PM.

Ultrafine particles in the nuclei-mode are typically formed as a result of gas-to-particle formation and vapor phase reactions upon the particles exiting the tailpipe (Kittleson, 2001). Studies have shown that the freshly emitted combustion diesel particles (<10 nm) quickly form agglomerated soot particles ranging from 30-50 nm. Typically, as the exhaust cools and dilutes, new nuclei mode particles are generated (Kittleson, 1998). In general, ultrafine particles are assumed to be spatially inhomogeneous, as the number concentration is thought to be strongly dependent on local contributions and proximity to sources, especially regarding near roadway concentrations. Recent studies have shown that ultrafine particle number concentrations typically decrease with increased distances downwind from major highway sources (Zhu et al., 2002,a,b, McAuley et al., 2010).

II. Background

A near roadside ultrafine particle study was recently carried out from May through June of 2010 at several locations surrounding four (4) busy intersections on Dorchester Avenue. The purpose was to provide a baseline, ultrafine particle pollution assessment. Prior to this study, no data regarding ultrafine particles had been collected on any of the monitored routes or other locations along Dorchester Avenue. Results from this study will be useful to help understand both traffic and ultrafine particle patterns, and concentrations in the areas monitored where UFP near roadside measurements were taken. This will be critical to plan and estimate other areas having similar traffic patterns to the routes currently selected for conducting additional near roadside monitoring along Dorchester Avenue. Dorchester, MA has previously been identified as an area having one of the highest asthma prevalence rates. The direct reason for this has not been identified, but there have

been several studies linking traffic combustion with increases in asthma and other respiratory health endpoints (Lwebuga-Mukasa and Dunn-Georgiou, 2000, Gaudermann et al., 1999 & 2004).

Vehicle counts on various areas on Dorchester Avenue have been shown to have an annual average of over 30,000. As a result of other studies describing health impacts (e.g., exacerbation of asthma) from acute and chronic ultrafine particle exposures, there may be a correlation between high asthma rates and traffic combustion exposures to those living on and near Dorchester Avenue, familiarly known as “Dot Ave.”.

III. Experimental Methods

A. Sampling

Near roadside ultrafine particle monitoring was conducted on several days from May through June of 2010 to capture AM and PM UFP concentrations. Staff was assigned to particular routes and within each route several monitoring sites (i.e. waypoints) were established. For both AM and PM measurements, monitoring was conducted at each waypoint for a total of five minutes.

Measurements conducted on a particular route in the AM were not always sampled again on the same day in the PM given time and staff constraints. Therefore, sampling times for available staff and times had to be split up. Total measurement time across all sites was typically sixty minutes including walk times between sites. A total of four routes were selected to be sampled. Table 1 provides a summary of ultrafine particle number concentrations determined by averaging available UFP data for all days monitoring was conducted within each route for comparing overall number concentrations across the different routes for AM and PM measurements. There were a total of three AM and three PM measurements for all routes at designated locations within each route. In addition, all routes contained a total of nine monitoring locations, with only Route 2 containing one additional monitoring site. Route 1 started at Dot Avenue & Adams Street and ended at 1234 Adams Street with nine locations selected for sampling to be conducted. Route 2 started at Dot Avenue & Adams Street (the two streets intersect again approximately two miles north of Route 1) and ended on Lincoln Avenue & Dot Avenue with a total of ten locations. Route 3 began at a Sunoco station (Dot Avenue/Freeport/Hancock) and ended at Ellsworth & Dot Avenue. Route 4 started at Columbia Road & Dot Avenue and ended at the intersection of East Cottage Street and Pond Street with a total of nine locations within the route.

B. Mobile Monitoring Methods

To define spatial patterns of UFP at the different locations on Dorchester Avenue, staff of the Dorchester Environmental Health Coalition carried a P-Trak ultrafine particle monitor (TSI, Inc) and a handheld Etrex Vista Global Positioning System (GPS) manufactured by Garmin.

Global Positioning System

Garmin's Etrex Vista GPS is a small cell phone-sized unit that provides location accuracy from three to twenty-two meters depending on satellite coverage and reception. It is capable of recording location, direction, and pace of travel. Locations were recorded every minute and were linked to measured concentrations through the date/time stamp. Therefore, synchronizing instrument times and ensuring clock drift were at a minimum, as were critical quality control functions that occurred daily.

Ultrafine Particle Counts

The TSI P-Trak Model 8525 (Shoreview, MN) was used to measure ambient UFP number concentrations within the size range of 0.02-1 μm in median aerodynamic diameter. The P-Trak uses an internal pump that draws the air through the instrument. As particles enter the P-Trak they pass through a saturator tube, where isopropyl alcohol evaporates into the sample stream, saturating the sample with alcohol vapor. The sample then goes to the cooled condenser tube where the alcohol vapor supersaturates and condenses onto the particles, increasing their diameters to over ten nanometers. These particles then pass through a small laser beam. The particles scatter this light and an optical system collects and focuses the light onto a photometer. The light signal is then converted into a particle count by the instrument. The high sensitivity and portable nature of the P-Trak 8525 made it ideal for this study. However, a limitation for this instrument is that alcohol is typically consumed within three hours and thus long-term sampling requires frequent visits to recharge the alcohol wick. P-Traks were zeroed daily with an external HEPA filter. All instruments were factory calibrated within the past year, as recommended by the manufacturer. As an additional check, all instruments were collocated prior to beginning sampling. Comparisons of the P-Trak with a general-purpose condensation particle counter (CPC) suggest that the P-Trak underreports particle counts when used in close proximity to combustion sources, such as traffic (Zhu, Yu et al. 2006). Correlations between the P-Trak and CPC improved with particle size and distance from the road.

Studies in Los Angeles by Zhu and colleagues (Zhu, Hinds, Kim, Shen et al. 2002; Zhu, Hinds, Kim, and Sioutas 2002; Zhu et al. 2004) show that UFP tend to drop off exponentially several hundred meters downwind.

IV. Results

Table 1 is a summary of ultrafine particle (UFP) number concentrations for each route and date monitoring was conducted for comparing overall number concentrations across the different sampling routes for the AM and PM monitoring periods. Overall, route 1 in comparison to the other routes was found to have very similar near roadside ultrafine particle concentrations for both AM (11,550 p/cm³ +/- 5,689) and PM (11,661 p/cm³ +/- 7,037) measurements, along with route 1 having the lowest AM (11,550 p/cm³ +/- 5,689) across all other routes. Route 4 was found to have the largest difference comparing AM (13,108 p/cm³ +/- 7,742) and PM (8,868 p/cm³ +/- 4,577) UFP concentrations along with route 4 having the overall lowest PM (8,868 p/cm³ +/- 4,577) UFP concentrations across all routes. Route 2 was found to have the highest AM (16,415 p/cm³ +/- 7,037) and PM (12,265 p/cm³ +/- 8,813) UFP concentrations across all other routes vs. route 1 (11,661 p/cm³ +/- 7,037), route 3 (10,972 p/cm³ +/- 8,729), and route 4 (8,868 p/cm³ +/- 4,577) across all monitoring days.

Table 2 is a summary of each individual route showing the specific waypoints that were found to have the overall highest and lowest ultrafine particle (UFP) number concentrations across the different waypoints within the designated routes for determining potential individual "hot-spot" locations. Route 2, waypoint 7 (58 Granger) was found to have the highest UFP particle concentration during AM (28,000 p/cm³ +/- 6,340) measurements versus any other waypoint for all routes for both AM and PM measurements. As noted above, route 2 had the overall highest UFP concentrations across all routes (see table 1). Although waypoint 9 (38 Dickens) had the lowest UFP concentration across all waypoints within route 2, results showed that, at waypoint 9, UFP concentrations were higher than other lower-reported UFP concentrations. The lowest UFP concentrations for all individual sites was on route 1, waypoint 9 (Dot Avenue S/Adams) where concentrations at this location for all monitoring days averaged (6,176 p/cm³ +/- 896). Route 3, waypoint 4 (Hancock) showed the largest variation in UFP range (11,984 p/cm³;36,536 p/cm³) versus all other individual sites.

V. Discussion

Several sites along Dorchester Avenue were recently sampled to better understand the concentrations of traffic-related combustion. Ultrafine particles were monitored using a standard method, and results indicated variations in ultrafine particles across and within the different routes designated as waypoints.

Overall, ultrafine particle concentrations were highest during the AM ($13,968 \text{ p/cm}^3$) monitoring versus PM ($10,900 \text{ p/cm}^3$) with a total difference across all sites of about $3,000 \text{ p/cm}^3$. Individual site analysis showed variation of ultrafine particle concentrations across the different waypoints within specific routes (see table 2). Despite Route 2 having an additional waypoint, (1-10) versus (1-9) for all other routes, individual waypoint analysis confirmed that waypoint 10 UFP concentrations were found to be similar and, in many cases, lower than the other nine waypoints in route 2. UFP concentrations comparing highest and lowest for each individual route revealed which locations were found to be highest and lowest, and both table 1 and table 2 results showed that route 2 did, indeed, have the largest, overall concentrations of ultrafine particles (i.e., waypoint 7, 58 Granger). Therefore, the extra waypoint location that was monitored, likely, did not result in higher UFP concentrations than all other routes described, but simply near roadside concentrations were higher for route 2 across all monitoring days. This is clearly shown in table 2, as route 2 had the highest UFP concentration range for both AM ($14,531 \text{ p/cm}^3$; $28,000 \text{ p/cm}^3$) and PM ($7,671 \text{ p/cm}^3$; $17,700 \text{ p/cm}^3$) measurements, indicating much more variation in near roadside UFP concentrations than all other routes.

In summary, ultrafine particle monitoring was conducted during morning and evening sampling campaigns during heavy traffic times. Analysis showed that there were a few locations that were identified as "hot-spot" locations resulting from consistently higher ultrafine particle concentrations. Despite these fluctuations and high levels of variation in ultrafine particles, in some cases, as shown in the individual analysis (table 2), the observed ultrafine particle concentrations at the different routes did not seem to indicate high levels of ultrafine particles as compared to other near road side studies. This is based on other near roadside studies where ultrafine particle concentrations average from $25,000$ to $80,000 \text{ p/cm}^3$ for several hours (McAuley et al., 2010^{1,2}). One limitation to the study may be a direct result of the instrumentation used. Since freshly generated ultrafine particles typically range from 6-10 nm, and then, through dilution and cooling, grow to 10-15 nm, much of

the number concentration may be lost due to the P-trak limit of detection (10 nm). This lower limit of detection at the 10 nm range also constitutes a fifty percent collection efficiency and, therefore, may result in additional undercounting.

VI. Conclusions and Recommendations

This study demonstrates that near roadside monitoring of ultrafine particle concentrations in various locations along Dorchester Avenue showed variations in ultrafine particle concentrations. However, based on the observed levels of ultrafine particles, it is not clear if the areas sampled are representative of other intersections along Dorchester Avenue. This study did provide some baseline ultrafine particle data to go forward with. It is important to note that the current study was conducted during the summer months where ultrafine particle concentrations would be lower vs. winter time from higher mixing heights and dilution ratios. Therefore, a follow up study at the same locations should be conducted during the winter. To determine comparability with other sites along Dorchester Avenue, new sites should be selected and across seasonal monitoring should be conducted.

I would like to personally thank Rosanne Foley and the member of the Dorchester Environmental Health Coalition for the opportunity to conduct this study and thank everyone for all of their diligence and attention to detail.

Sincerely,



Timothy R. McAuley, MS, PhD
President and Founder, CHANGE
Consulting for Health, Air, Nature, & a Greener Environment

Appendix A.

Table 1. Summary of ultrafine particle (UFP) number concentrations for each route and date monitoring was conducted for comparing overall number concentrations across the different sampling routes for the AM and PM monitoring periods.

Route	Waypoints	Mean UFP (p/cm ³) +/- SD	^B Range	^A N	Number of Monitoring Days	Dates of Monitoring Conducted
<i>AM Measurements</i>						
1	1-9	11,550 +/- 5,689	(8,800;15,291)	154	3	5/26, 5/28, & 6/2
2	1-10	16,415 +/- 7,037	(14,531;28,000)	180	3	5/27, 6/7, & 6/14
3	1-9	14,799 +/- 7,867	(11,179;21,200)	162	3	5/26, 6/8, & 6/9
4	1-9	13,108 +/- 7,742	(9,000;21,500)	162	3	5/27, 6/1, & 6/8
<i>PM Measurements</i>						
1	1-9	11,661 +/- 7,037	(6,176;14,428)	159	3	5/27, 6/7, & 6/8
2	1-10	12,265 +/- 8,813	(7,671;17,700)	174	3	5/26, 6/15, & 6/17
3	1-9	10,972 +/- 8,729	(6,300;16,332)	162	3	6/7, 6/11, & 6/14
4	1-9	8,868 +/- 4,577	(6,500;13,700)	162	3	5/26, 5/28, & 6/2

^AN-total represents the total sum of all 5 minute sampling periods for each date when data was collected during each AM and PM measurements.

^BRange (p/cm³) is presented, indicating the lowest and highest values across the waypoints for all days monitored for each route and either AM or PM measurements.

Table 2. Summary of each individual route showing the specific waypoints that were found to have the overall highest and lowest ultrafine particle (UFP) number concentrations across the different waypoints within the designated route.

^A Route/Time	Highest UFP (p/cm ³) +/- SD	WP	Location	^B Range	Lowest UFP (p/cm ³) +/- SD	WP	Location	Range
1/ AM	15,291 +/- 4,677	1	Dot Ave/Adams	(12,070;18,963)	8,800 +/- 431	5	Richmond/Butler	(7,900;10,500)
1/ PM	14,428 +/- 8,500	4	Richmond/Dot Ave	(10,000;16,713)	6,176 +/- 896	9	Dot Ave S/Adams	(3,200;11,406)
2/ AM	28,000 +/- 6,340	7	58 Granger	(5,579;45,032)	14,531 +/- 464	9	38 Dickens	(8,361;18,505)
2/ PM	17,700 +/- 5,155	8	Clayton/Leonard	(13,600;21,200)	7,671 +/- 300	9	38 Dickens	(3,460;9673)
3/ AM	21,200 +/- 5,900	4	Hancock	(11,984;36,536)	11,180 +/- 1,486	6	8 Hecla St	(6,400;16,245)
3/ PM	16,323 +/- 8,328	1	Sunoco St	(8,850;27,000)	6,300 +/- 481	7	Hecla/Adams	(4,301;8,171)
4/ AM	21,500 +/- 10,200	1	Dot Ave/Columbia Rd	(16,200;25,000)	9,000 +/- 585	3	Roseclair/Mayhew St	(8,600;9,300)
4/ PM	13,700 +/- 2,700	1	Dot Ave/Columbia Rd	(8,200;18,000)	6,500 +/- 1,721	6	Grafton/Buttonwood	(6,500;6,800)

^AAM & PM data presented under Route/Time represents an examining of all data collected for AM or PM, respectively to determine the waypoints that showed consistently higher and lower UFP concentrations across all monitoring days.

^BRange is represented as the lowest and highest UFP concentrations for all monitoring days on that specific route for that specific waypoint for both high and low concentrations.

VII. References

Vedal, S. (1997) Ambient Particles and Health: Lines that Divide, *J. Air and Waste Mgmt Assoc.* 47: 551-581.

Dockery DW, Pope CA, and Xu X., et al. (1993). An association between air pollution and mortality in six US cities, *N Engl J Med.* 329:1753-1759.

Osunsanya, T., Prescott, G., and Seaton, A. (2001). Acute Respiratory Effects of Particles: Mass or Number, *Occup Environ Med.* 58:154-159.

Peters JM, Avol E, Navidi W, London S, Gauderman WJ, Lurmann F, et al. A study of twelve Southern California communities with differing levels and types of air pollution. II, *Am J Respir. Crit Care Med.* 159:760-7.

Yue, W., Schneider, A., Stozel, M., Ruckerl, R., Cyrus, J., Pan, X.C., Zareba, W., Koenig, W.G., Wichmann, H.E., and Peters, A. (2007). Ambient source-specific particles are associated with prolonged repolarization and increased levels of inflammation in male coronary artery disease patients, *Mutation Research-Fundamental and Molecular Mechanisms of Mutagenesis.* 621: 50-60.

Kittleson, D., Watts, W., and Johnson, J. (2001). Fine particle (Nanoparticle) Emissions on Minnesota Highways, Final Report, Minnesota Department of Transportation.

Kittleson, D. (1998). Engines and nanoparticles: a review, *J Aero Sci*, 29(5/6):575-588.

McAuley TR, Fisher R, Zhou X, Jaques PA, and Ferro AR. (2010). Relationships of outdoor and indoor ultrafine particles at residences downwind of a major international border crossing in Buffalo, NY. *Accepted 2010 Indoor Air.*

McAuley, T.R., Ferro, A.R., Jaques, P.A., and Hopke, P.K. (2009) "Spatial measurements of nanoparticles using an Engine Exhaust Particle Sizer within a local community downwind of a major international trade bridge in Buffalo, N.Y." *Accepted 2010, Aerosol Sci Technol.*

Zhu, Y., Hinds, W., Kim, S., and Sioutas, C. (2002) (a). Concentration and size distribution of ultrafine particles near a major highway. *J. Air & Waste Manage. Assoc.*, 52:1032-1042.