HEI Non-tailpipe Emissions Study: Characterization of Coarse and Fine Ambient PM and Road Dust Near Major Roads in the Greater Boston Area

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Study Design

Study Area: Greater Boston Metropolitan Area

Number of Sites: 27 major roads

At each road, we collected samples at a series of 3 distances away from the road: <25 m, 50-200 m and >500 m

Most road sites were sampled once, a subset were sampled multiple times (including different seasons)

Study Design

At each site:

- One hour ambient $PM_{0.2\text{-}2.5}$ and $PM_{2.5\text{-}10}$ using **particle concentrators**
- $PM_{2.5}$ and PM_{10} aerosolized dust from the road surface (< 5 min)
- Pooled ambient (non-concentrated) $PM_{0.2}$
- Trace elements (XRF), EC/OC (TOR)
- Roadside, intermediate and background locations sampled in random order during a single day.

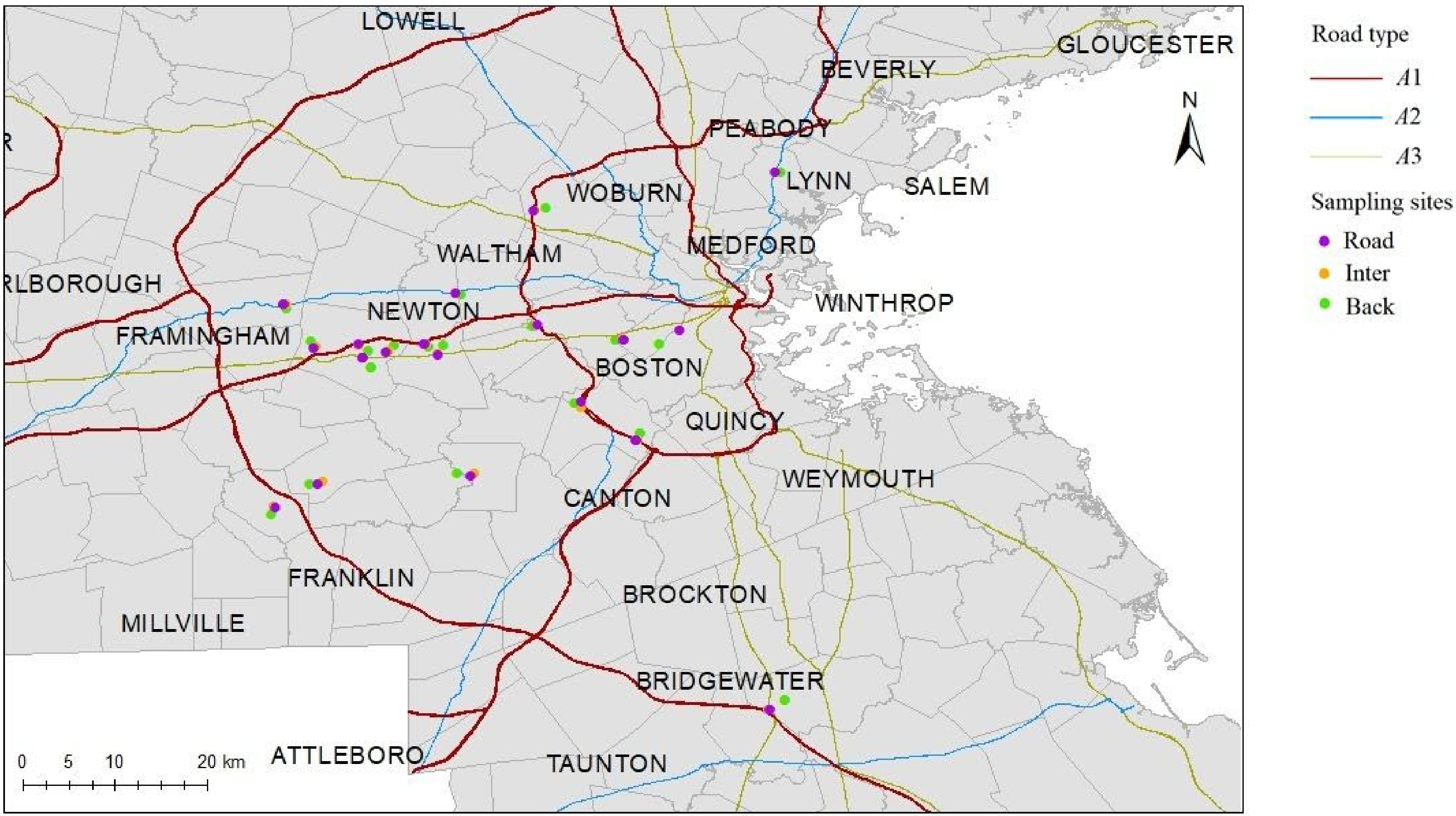
Simultaneously at roadside, intermediate, background:

- Weather (temp, wind speed/direction, humidity, pressure)
- Continuous PM and particle count (optical sensor)
- Traffic (recorded video image)

Mobile Particle Concentrator Platform

Road Dust Aerosolization Sampler

Sampling sites around Greater Boston area



Analysis: Ambient Coarse and Fine PM

$$\ln(C_{ij}) = \beta_{0j} + y_{ij} + \beta_{1j} \times \boldsymbol{ln(d_j)} + \beta_{2j} \times season + e_{ij}$$

where

- C_{ij} is the concentration of element *j* (or total particle mass) at road *i* (μg/m^3);
- β_{0j} is the fixed intercept;
- y_{ij} is the random intercept for road date *i*;
- $\ln(d_j)$ is the natural log of perpendicular distance from sample location to road (m);
- β_{1j} is the slope for the distance to road parameter;
- $season$ is a dichotomous variable for the season when the sample was collected;
- β_{2j} is the slope for the season parameter;
- e_{ij} represents random error.

The model was fit separately for coarse and fine particles for each element and for total particle mass. In this analysis, we included only elements whose sample concentrations were greater than sample uncertainties for at least 60% of the samples.

	Coarse			Fine		
Element	Slope, β_{1j}	SE	p-value	Slope, β_{1j}	SE	p-value
PM	-0.295	0.181	0.104	**-0.037**	**0.018**	**0.036**
Na	-0.260	0.156	0.096	-0.003	0.043	0.951
Mg	-0.200	0.150	0.181	0.007	0.033	0.842
Al	-0.270	0.159	0.091	**-0.194**	**0.046**	**<0.001**
Si	-0.273	0.165	0.098	-0.033	0.033	0.315
S	-0.275	0.150	0.066	-0.022	0.021	0.283
Cl	**-0.307**	**0.152**	**0.044**	-0.044	0.036	0.209
K	-0.244	0.153	0.111	-0.019	0.023	0.415
Ca	-0.269	0.158	0.090	**-0.069**	**0.028**	**0.013**
Ti	**-0.340**	**0.150**	**0.023**	**-0.192**	**0.035**	**<0.001**
V	**-0.366**	**0.141**	**0.010**	*		
Cr	**-0.373**	**0.135**	**0.006**	**-0.222**	**0.050**	**<0.001**
Mn	**-0.281**	**0.139**	**0.043**	**-0.141**	**0.052**	**0.007**
Fe	**-0.364**	**0.164**	**0.027**	**-0.218**	**0.032**	**<0.001**
Co	**-0.562**	**0.165**	**0.001**	*		
Ni	*			-0.126	0.075	0.092
Cu	**-0.420**	**0.143**	**0.003**	**-0.160**	**0.029**	**<0.001**
Zn	**-0.319**	**0.140**	**0.023**	**-0.144**	**0.035**	**<0.001**
Br	-0.199	0.153	0.194	-0.028	0.0549	0.609
Sr	**-0.270**	**0.134**	**0.043**	0.056	0.043	0.196
Zr	**-0.560**	**0.139**	**<0.001**	*		
Sn	**-0.308**	**0.147**	**0.036**	0.028	0.061	0.651
Ba	**-0.502**	**0.179**	**0.005**	*		
Pb	-0.267	0.138	0.053	-0.055	0.050	0.269

Results: Ambient Fine PM Carbon Fraction

$PM_{0.2-2.5}$ ($\mu g/m^3$)	Model Output	Distance [ln]	wind [not downwind]	Season [warm]	Road type [A3]
OC	Estimate	-0.0015	0.1603	**-1.0521**	0.0912
	p-value	0.975	0.441	**0.017**	0.802
EC	Estimate	-0.0054	*-0.0286*	0.0047	-0.0005
	p-value	0.156	*0.072*	0.820	0.979
TC	Estimate	-0.0260	-0.0311	**0.3753**	-0.2326
	p-value	0.209	0.734	**0.024**	0.106
OC1	Estimate	-0.0005	-0.0004	**0.0080**	-0.0006
	p-value	0.323	0.865	**0.007**	0.834
OC2	Estimate	*-0.0041*	-0.0012	**0.0533**	-0.0091
	p-value	*0.069*	0.898	**0.001**	0.524
OC3	Estimate	-0.0114	-0.0154	**0.1869**	**-0.1658**
	p-value	0.263	0.734	**0.042**	**0.030**
OC4	Estimate	*-0.0057*	-0.0064	*0.0499*	-0.0201
	p-value	*0.087*	0.661	*0.060*	0.384
EC1	Estimate	-0.0048	-0.0195	0.0124	-0.0130
	p-value	0.166	0.174	0.499	0.461
EC2	Estimate	-0.0006	*-0.0078*	-0.0059	0.0085
	p-value	0.559	*0.053*	0.316	0.123
EC3	Estimate	-0.0001	-0.0020	-0.0019	0.0035
	p-value	0.891	0.474	0.536	0.249
Pyrolysis OC	Estimate	0.0016	0.0165	**0.0720**	-0.0356
	p-value	0.725	0.394	**0.023**	0.212
Optical EC	Estimate	**-0.0016**	0.0003	0.0043	-0.0029
	p-value	**0.010**	0.898	0.203	0.372

Analysis: Road Dust PM_{10} and $PM_{2.5}$

$$\ln(C_{ij}) = \beta_{0j} + y_{ij} + \beta_{1j} \times \boldsymbol{ln(d_j)} + \beta_{2j} \times season + \beta_{3j} \times rt_{ij} + e_{ij}$$

where

- C_{ij} is the mass fraction of element *j* at road *i* (μg/mg);
- β_{0j} is the fixed intercept;
- y_{ij} is the random intercept for road date *i*;
- $\ln(d_j)$ is the natural log of perpendicular distance from sample location to road (m);
- β_{1j} is the slope for the distance to road parameter;
- $season$ is a dichotomous variable for the season when the sample was collected;
- β_{2j} is the slope for the season parameter;
- rt_{ij} is a dichotomous variable for the road classification (highway vs busy minor);
- β_{3j} is the slope for the roadway parameter;
- e_{ij} represents random error.

The model was fit separately for both fractions of road dust. In this analysis, we included only elements whose sample concentrations were greater than sample uncertainties for at least 80% of the samples.

Results: Road Dust PM_{10} and $PM_{2.5}$ Decay

Element	PM_{10}		$PM_{2.5}$	
	β_{1i} (95%CI)	p-value	β_{1i} (95%CI)	p-value
Na	-0.017 (-0.081, 0.048)	0.617	-0.011 (-0.086, 0.063)	0.768
Mg	0.010 (-0.035, 0.055)	0.656	0.023 (-0.022, 0.068)	0.327
Al	0.029 (-0.002, 0.060)	0.070	0.024 (-0.001, 0.048)	0.059
Si	0.026 (-0.002, 0.055)	0.078	0.018 (-0.002, 0.039)	0.084
Cl	**-0.089 (-0.157, -0.021)**	**0.013**	**-0.113 (-0.176, -0.050)**	**0.001**
K	0.018 (-0.001, 0.037)	0.062	0.006 (-0.010, 0.022)	0.458
Ca	**-0.035 (-0.068, -0.002)**	**0.040**	**-0.050 (-0.087, -0.012)**	**0.012**
Ti	**-0.031 (-0.054, -0.007)**	**0.012**	**-0.050 (-0.074, -0.026)**	**<0.001**
V	-0.008 (-0.053, 0.038)	0.745	-0.016 (-0.076, 0.045)	0.619
Cr	**-0.064 (-0.093, -0.034)**	**<0.001**	**-0.065 (-0.099, -0.032)**	**<0.001**
Mn	-0.017 (-0.053, 0.019)	0.362	**-0.052 (-0.082, -0.022)**	**0.001**
Fe	**-0.031 (-0.045, -0.016)**	**<0.001**	**-0.043 (-0.059, -0.027)**	**<0.001**
Co	**-0.071 (-0.119, -0.022)**	**0.006**	-0.042 (-0.109, 0.025)	0.224
Ni	-0.024 (-0.058, 0.010)	0.171	**-0.050 (-0.092, -0.008)**	**0.025**
Cu	**-0.126 (-0.166, -0.087)**	**<0.001**	**-0.141 (-0.187, -0.094)**	**<0.001**
Zn	**-0.094 (-0.127, -0.060)**	**<0.001**	**-0.109 (-0.143, -0.075)**	**<0.001**
Sr	-0.010 (-0.048, 0.027)	0.588	0.014 (-0.031, 0.059)	0.555
Zr	**-0.105 (-0.161, -0.049)**	**0.001**	-0.178 (-0.266, -0.089)	<0.001
Ba	**-0.138 (-0.213, -0.063)**	**0.001**	-	-
Pb	**-0.064 (-0.121, -0.007)**	**0.033**	-0.063 (-0.132, 0.006)	0.079

Decay rates => Tracers

Strong	Weak	No
Cu. Fe	Ni	BC
Zn, Cr	V	S
Sn, Sr	Cl	Si
Co, Mn	Ti	Al
Ba, Zr		Na
		Ca
		Pb

Tailpipe

Conclusions

- Development of the necessary hardware to measure particle composition
  - Technologies to collect coarse and fine PM at high flow rates
  - Road dust sampler to collect coarse and fine surface particles
- The study design was successfully implemented
  - Elemental concentrations were mostly above detection limits
  - The selection of three positions was quite important to examine exposure profiles
  - The results suggest many elements that can be used as tracer of non-tailpipe emissions

Conclusions

- Decay of air pollution as a function of log(distance) from road, consistent with findings from epidemiological studies
  - Stronger for PM_{10} than $PM_{2.5}$
  - Stronger for elements mostly associated with non-tailpipe traffic emissions
  - Non-tailpipe metals are present in both coarse and fine ambient particles
- Only slight decay with distance observed for EC, OC and most fractions
  - Reduced tailpipe emissions of EC
  - Urban/regional background is high
  - Many other local sources of EC and OC

- Non-tailpipe metals are present in both coarse and fine dust
  - Seasonal effect, levels higher during warm season
  - No difference in EC, OC, or fractions– asphalt?

AWMA Special Issue:

- Koutrakis P. and Greenbaum D. Editorial.
- Huang S, Taddei P, Lawrence J, Martins MAG, Li J, Koutrakis P. Trace element mass fractions in road dust as a function of distance from road. *J. Air Waste Manage.*, 2020 (Accepted)
- Lawrence J, Martins M, Liu M, Koutrakis P. Measurement of the gross alpha activity of the fine fractions of road dust and near-roadway ambient particle matter. *J. Air Waste Manage.* (Accepted)
- Martins M, Lawrence J, Ferguson S, Wolfson JM, Koutrakis P. Development, and evaluation of a mobile laboratory for collecting short-duration near-road fine and coarse ambient particle and road dust samples. *J. Air Waste Manage.*, 2020 (Accepted)
- Moreira TCL, Huang S, Lawrence J, Martins M, Wolfson JM, Ferguson ST, Koutrakis P. Influence of road proximity on the ambient concentrations of organic and elemental carbon fractions in coarse and fine particulate matter. *J. Air Waste Manage.*, 2020 (under review)
- Silva E, Huang S, Lawrence J, Martins M, Li J, Koutrakis P. Trace element concentrations in ambient air as a function of distance from road. *J. Air Waste Manage.*, 2020 (Accepted)

THANKS