Analysis of Mobile Source Air Toxics (MSATS)–Near-Road VOC and Carbonyl Concentrations

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Abstract

This presentation examines data from a year-long study of measured near-road mobile source air toxic (MSAT) concentrations and compares these data with modeled 2005 National Air Toxic Assessment (NATA) results. Field study measurements were collected during a field campaign in Las Vegas, Nevada from mid-December, 2008 through mid-December, 2009. MSAT measurements included VOC (1,3-butadiene, benzene) and carbonyl (acrolein, acetaldehyde and formaldehyde) compounds. The data were compared with relevant census tract NATA estimates for 1,3-butadiene, benzene, acrolein, acetaldehyde and formaldehyde. NATA total ambient benzene concentrations were much higher relative to the measured benzene values, while NATA total acrolein values were much lower than measured acrolein values. NATA total acetaldehyde and formaldehyde concentrations for all wind conditions and downwind conditions were also much lower than measured acetaldehyde and formaldehyde concentrations. Plausible reasons for these differences include nearby sources influencing the measured values; meteorological influences may not be well captured by the NATA modeling regime; and atmospheric chemistry of measured compounds. Moreover, additional explanatory variables may be needed for certain urban areas in order to accurately disaggregate anthropogenic air toxics emissions (Kimbrough, et al., 2014). Predicted NATA acrolein values (total ambient) were a factor of 10 less than the measured values. Uncertainties in the sample collection and analysis of acrolein and uncertainties in existing emission inventories are the most probable explanations for these differences as well as secondary chemical reactions taking place (Kimbrough, et al., 2014).

Kimbrough, S., T. Palma, and R.W. Baldauf. Analysis of mobile source air toxics (MSATs)—Near-road VOC and carbonyl concentrations. Journal of the Air & Waste Management Association 64, no. 3 (2014/03/04 2014): 349-59. doi:10.1080/10962247.2013.863814

Methods/Instruments

Measurement Parameter	Distance from I-15 (m)				Sampling Approach	Instrument Data			
	Upwind	Downwind							
	100	20	100	300		Make/Model	Accuracy	Precision	Detection Limit	Sample Type and Frequency
Acetaldehyde	X	X	X	X	U.S.EPA Method TO-11A	Atec 2200 Cartridge Sampler	± 2 % ± 2 % N/A	± 2 % ± 2 % N/A	± 2 % ± 2 % N/A	1-hour integrated 1-in-12 day schedule 9 samples each day at each road-side location
Formaldehyde	X	X	X	X						
Acrolein	X	X	X	X	U.S.EPA Method TO-15	Entech 1800 Canister Sampler	± 2 % ± 2 % N/A	± 2 % ± 2 % N/A	± 2 % ± 2 % N/A	
Benzene	X	X	X	X						
1,3-Butadiene	X	X	X	X						
Wind Speed	X	X	X	X	sonic anemometer	RM Young Model 81000	±0.05 m/s	std. dev. 0.05 m/s at 12 m/s	0.01 m/s	Continuous (5 minute)
Wind Direction							± 5°	± 10°	0.1°	
Met tower height above ground level (m) -- includes shelter height: 11.8						Not applicable				---
Traffic (vehicle counts, speed)	Data provided by Nevada DOT				radar	Radar (Wavetronix)				Continuous (15 minutes)

Summary of canister (TO-15) and cartridge (TO-11A) samples collected.

Sample type	No. of samples	% by sample type†	No. of total samples with no sample collection errors/ warnings	% of total samples with no sample collection errors/warnings†	No. of total samples with sample collection errors/ warnings	% of total samples with sample collection errors/ warnings†
TO-15–1,3-butadiene and benzene.						
Field Blank	69	4	55	80	14	20
Field Control	69	4	56	80	13	20
Field Duplicate	69	4	52	75	17	25
Lab Duplicate	108	7	89	82	19	18
System Test	44	3	---	---	---	---
Sample	1185	77	1019	86	166	14
Total	1544		1271		229	
TO-11A– acrolein, acetaldehyde, and formaldehyde.						
Field Blank	67	5	53	4	14	21
Field Control	72	5	51	4	21	29
Field Duplicate	67	5	33	2	34	51
Lab Duplicate	2	0	0	0	2	100
System Test	20	1	---	---	---	---
Sample	1191	84	812	68	379	32
Total	1419		969		450	

†Percentages shown are based on percent of total samples collected. Percentages may not total to 100% due to rounding.

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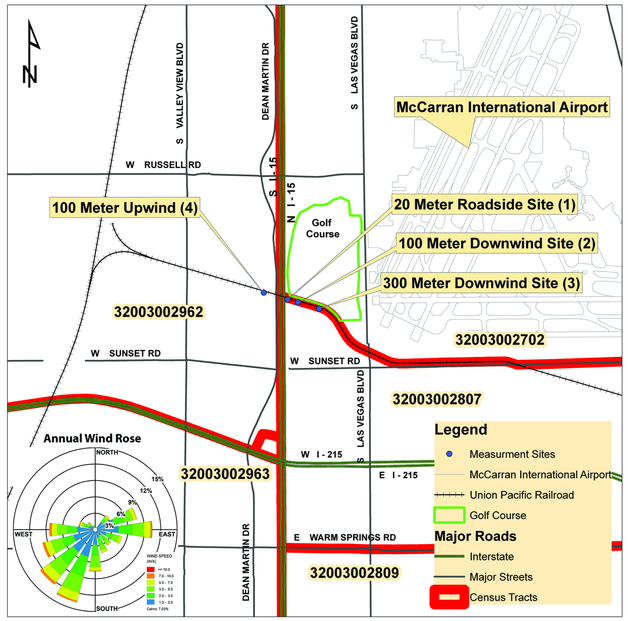
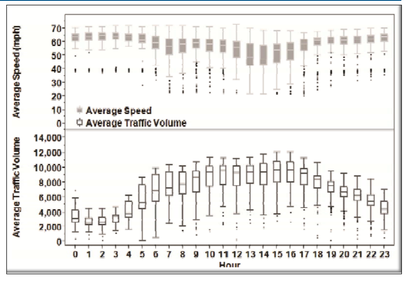
Sampling Location, Meteorology

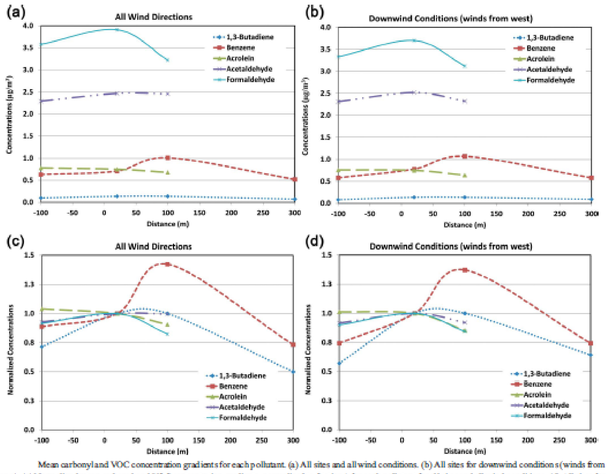


Results

- Traffic Speed/Volume



- Concentrations – VOC & Carbonyl



Mean carbonyl and VOC concentration gradients for each pollutant. (a) All sites and all wind conditions. (b) All sites for downwind conditions (winds from west). (c) Normalized mean carbonyl and VOC concentration gradients, normalized to Station 1 for each pollutant for all sites and all wind conditions. (d) All sites for downwind conditions (winds from west). Normalized means for each site shown in (c) and (d) were calculated as follows: V_{ps}/V_{p1}, where V = average value, p = pollutant, s = site, s1 = site 1.

Results

NATA total annual average ambient concentrations and total on-road mobile annual average ambient concentrations for adjacent census tracts relative to census tracts with measurement stations (EPA, 2005)

Census tract	Total annual average ambient concentration (µg/m³) 1,3-Butadiene	Acrolein	Acetaldehyde	Benzene	Formaldehyde	Total annual on-road mobile average ambient concentration (µg/m³) 1,3-Butadiene	Acrolein	Acetaldehyde	Benzene	Formaldehyde
32003002702	0.16	0.07	2.41	1.32	2.98	0.06	0.01	0.08	0.39	0.13
32003002807	0.20	0.07	2.44	1.71	2.98	0.12	0.01	0.16	0.79	0.27
32003002809	0.16	0.06	2.37	1.46	2.84	0.08	0.01	0.11	0.55	0.18
32003002962	0.09	0.05	2.28	1.01	2.68	0.02	0.002	0.02	0.12	0.04
32003002963	0.07	0.02	1.56	0.99	1.60	0.004	0.002	0.02	0.12	0.04

NATA total annual average ambient concentrations and total on-road mobile annual average ambient concentrations (EPA, 2005) versus measured (100 m) upwind and downwind (20 m, 100 m, and 300 m) concentrations and mean ambient measured concentrations across three downwind sites for all wind conditions and downwind conditions (winds from west)

Pollutant	NATA total annual average CT 32003002962†	NATA total annual on-road mobile CT 32003002962†	Measured ambient concentrations (all wind directions) 100 m upwind	NATA total annual average CT 32003002807*	NATA total annual on-road mobile CT 32003002807*	Measured ambient concentrations (all wind conditions) 20 m Downwind	100 m Downwind	300 m Downwind
1,3-Butadiene	0.09	0.02	0.10	0.20	0.12	0.14	0.14	0.07
Benzene	1.01	0.12	0.63	1.71	0.79	0.71	1.01	0.52
Acrolein	0.05	0.002	0.78	0.07	0.01	0.75	0.68	—
Acetaldehyde	2.28	0.02	2.29	2.44	0.16	2.47	2.46	—
Formaldehyde	2.68	0.04	3.58	2.98	0.27	3.91	3.22	—
Freeway								
	NATA total annual average CT 32003002962†	NATA total annual on-road mobile CT 32003002962†	Measured ambient concentrations (winds from west) 100 m upwind	NATA total annual average CT 32003002807*	NATA total annual on-road mobile CT 32003002807*	Measured ambient concentrations (winds from west) 20 m Downwind	100 m Downwind	300 m Downwind
1,3-Butadiene	0.09	0.02	0.08	0.20	0.12	0.14	0.14	0.09
Benzene	1.01	0.12	0.58	1.71	0.79	0.78	1.07	0.58
Acrolein	0.05	0.002	0.002	0.07	0.01	0.75	0.64	—
Acetaldehyde	2.28	0.02	2.31	2.44	0.16	2.52	2.32	—
Formaldehyde	2.68	0.04	3.33	2.98	0.27	3.70	3.12	—

Notes: †Census tract location for Station 4. *Census tract location for Station 1, Station 2, Station 3.

VOC and carbonyl—Averages for all wind directions and winds from west (12/15/2008–12/15/2009) and national ambient air concentrations for selected MSATs (EPA, 2010c)

Distance from road	All wind directions N (obs.)	Median (µg/m³)	Avg. (µg/m³)	95% CI (µg/m³)	Winds from west N (obs.)	Median (µg/m³)	Avg. (µg/m³)	95% CI (µg/m³)	National ambient air concentrations 2007 Median (µg/m³)	2007 Avg. (µg/m³)	2008 Median (µg/m³)	2008 Avg. (µg/m³)	2009 Median (µg/m³)	2009 Avg. (µg/m³)	2010 Median (µg/m³)	2010 Avg. (µg/m³)
1,3-Butadiene																
100 m Upwind	251	0.05	0.10	0.08–0.12	97	0.03	0.08	0.06–0.10	0.09	0.17	0.07	0.13	0.07	0.12	0.06	0.11
20 m Roadside	276	0.08	0.14	0.12–0.15	111	0.09	0.14	0.12–0.17								
100 m Downwind	246	0.08	0.14	0.12–0.17	85	0.11	0.14	0.11–0.16								
300 m Downwind	246	0.04	0.07	0.06–0.08	99	0.04	0.09	0.07–0.11								
Benzene																
100 m Upwind	251	0.47	0.63	0.56–0.69	97	0.45	0.58	0.48–0.69	0.88	1.16	0.82	1.03	0.81	0.96	0.80	0.95
20 m Roadside	276	0.52	0.71	0.65–0.78	111	0.58	0.78	0.68–0.88								
100 m Downwind	246	0.85	1.01	0.92–1.11	85	1.02	1.07	0.94–1.20								
300 m Downwind	246	0.36	0.52	0.46–0.58	99	0.39	0.58	0.48–0.68								
Acrolein																
100 m Upwind	279	0.52	0.78	0.73–0.83	104	0.52	0.76	0.68–0.84	0.31	0.70	0.66	0.89	0.35	0.75	0.40	0.73
20 m Roadside	308	0.52	0.75	0.71–0.80	109	0.52	0.75	0.67–0.82								
100 m Downwind	225	0.52	0.68	0.63–0.72	75	0.52	0.64	0.56–0.71								
300 m Downwind	—	—	—	—	—	—	—	—								
Acetaldehyde																
100 m Upwind	279	2.12	2.29	2.13–2.46	104	2.47	2.31	2.05–2.58	1.56	2.06	1.39	1.76	1.41	1.73	1.52	1.82
20 m Roadside	308	2.24	2.47	2.29–2.66	109	2.57	2.52	2.25–2.79								
100 m Downwind	225	2.31	2.46	2.27–2.66	75	2.53	2.32	2.04–2.60								
300 m Downwind	—	—	—	—	—	—	—	—								
Formaldehyde																
100 m Upwind	279	3.25	3.58	3.35–3.81	104	3.15	3.33	2.99–3.67	2.72	3.67	2.42	3.77	2.43	2.68	2.62	3.02
20 m Roadside	308	3.41	3.91	3.65–4.17	109	3.37	3.70	3.35–4.06								
100 m Downwind	225	3.21	3.22	3.00–3.43	75	3.22	3.12	2.76–3.47								
300 m Downwind	—	—	—	—	—	—	—	—								

Notes: N = number of valid integrated samples. Median = value for which 50% of values are higher and 50% are lower. Avg. = arithmetic average. CI = confidence interval.

Conclusions

- Formaldehyde had the largest absolute gradient under all wind conditions and for only downwind conditions;
- 1,3-butadiene and benzene had the largest relative gradients when examining normalized concentrations based on the 20 m measurements;
- Average concentrations of benzene were higher at the 100-m downwind site,
  - ➢ Other sources may have contributed to benzene emission (e.g., adjacent parking lot),
- Spatial gradients for the MSATs measured were not as pronounced as other pollutants gradients
- Uncertainties exist with both modeled (NATA) values and measurement techniques; issues include:
  - ➢ Local-scale meteorology,
  - ➢ Fine-scale ambient gradients,
  - ➢ Additional explanatory variables may be needed to disaggregate air toxics emissions,
- Measured concentrations compared well with NATA total ambient concentrations;.
- Measured concentrations did not compare well with on-road predicted NATA concentrations possibly due to background/secondary formation scenarios.

Reference

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