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Analytical Tools for Air Toxics and $PM_{2.5}$ Source Apportionment

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Applications

- $PM_{2.5}$ Attainment Demonstrations
- Community Air Toxics Studies
- EPA School Air Toxics Monitoring Program
- Health Risk Assessments
- Risk Communication
- Air Toxics Litigation

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EPA Draft Policy Assessment on Revisions to Fine Particle NAAQS (March 2010)

- Two scenarios under consideration:

  - annual standard of 12-13 $\mu g/m^3$ and 24-hour standard 30-35 $\mu g/m^3$

  - annual standard of 10-11 $\mu g/m^3$ and 24-hour standard 25-30 $\mu g/m^3$
- Recommendation for a 1-hour visibility standard (10-30 $\mu g/m^3$ daily maximum or 64-191 Mm^{-1} light extinction)
- Fine particle proposal expected in July 2010
- Coarse particle standards under review

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Overview of Analytical Tools - Weight-of-Evidence Approach

1) Spatial Zone of Influence Studies using Ambient Air Quality and Meteorological Monitoring Data
2) Receptor Modeling (e.g., Chemical Mass Balance)
3) Dispersion Modeling
4) Technical Approaches to Health Risk Assessments

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Case Studies

- Birmingham $PM_{2.5}$ Attainment Demonstration
- Cleveland $PM_{2.5}$ Source Allocation Study
- Birmingham Air Toxics Study (2005-2006)
- Tonawanda Community Air Quality Study (2007-2008)
- EPA School Air Toxics Monitoring Initiative
- Population-Based Health Risk Assessments

1) Spatial Zone of Influence Studies

- Examine spatial and temporal (e.g., time-of-day, day-of-week) variations in pollutant concentrations using meteorological and ambient air quality data from a multi-station monitoring network
- Chemical speciation of PM and/or gaseous HAPs
- Time-weighted pollutant concentration as a function of wind direction (e.g., pollution rose)

2) Receptor Modeling

- Used for estimating *generic* source contributions of PM or volatile HAPs using chemically speciated ambient monitoring data
- Two types of receptor models:
  - Chemical Mass Balance (CMB)
  - Factor Analysis (e.g., Positive Matrix Factorization)

Advantages of Receptor Models

- Based on actual monitoring data
- Do not have to quantify emissions
- Useful for estimating source contributions from widespread regional- and urban-scale sources (e.g., mobile sources, biomass combustion, area sources such as gas stations, sewage treatment plants, etc.) whose emissions are difficult to quantify and are difficult to apply in a dispersion model

Chemical Mass Balance (CMB) Receptor Model

$$C_{ik} = \Sigma\, a_{ij}\, S_{jk} \text{ for } i = 1,n$$

where,

C_{ik} = monitored concentration of component i in the kth sample

a_{ij} = fractional amount of component i in the emissions from source j

S_{jk} = source contribution of source j at the monitor for the kth sample

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CMB Assumptions

- Compositions of source emissions are constant
- Components do not react with each other (i.e., they add linearly)
- p-identified sources contribute to the receptor (monitor)
- The number of sources, p, is less than or equal to the number of components
- The compositions of all p sources (the set of a_{ij} for each S_{jk}) are linearly independent of each other

3) Dispersion Modeling

- Source-oriented: requires emission rates, source configuration and release parameters, hourly meteorological data, terrain and land use data
- U.S. EPA AERMOD Model for local impact assessments (i.e., $\leq$ 50 km)
- Puff models (e.g., CALPUFF) or grid models (e.g., CMAQ) for regional studies
- Complicating effects of chemistry and deposition

Advantages of Dispersion Modeling

- Evaluation of facility-specific air quality impacts on a pollutant-by-pollutant basis
- Interactive modeling of multiple sources
- Impact evaluation of alternative emission control strategies and changes to source parameters (e.g., stack height)
- Impact evaluation of regional-, urban-, and local-scale sources

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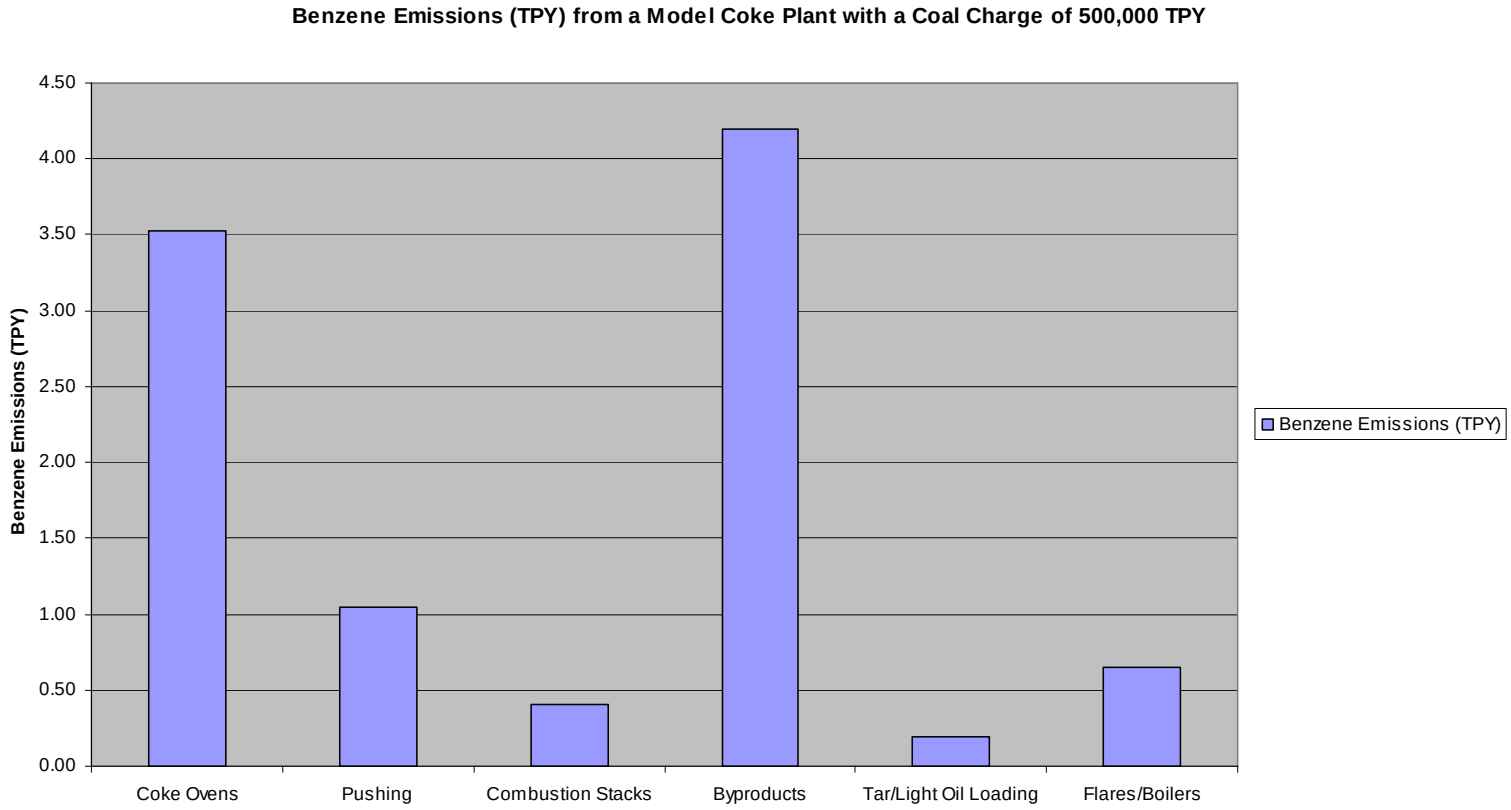
Coke Plant Benzene Emissions



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Source Characterization for Coke Battery Emissions

- Critical need to account for buoyancy enhancement caused by radiation heat transfer off the hot battery surfaces and convective heat transfer due to hot fugitive emissions from charging, door & topside leaks, and pushing
- Hybrid modeling approach using EPA BLP Model to predict buoyant line plume rise
- Predicted effective stack heights of 70-90 meters for ABC Coke and Walter Coke batteries

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Case Study #1: Birmingham $PM_{2.5}$ Attainment Demonstration

- Intensive study of $PM_{2.5}$ sources, using aerometric monitoring data from a multi-station network
- Development/refinement of a local $PM_{2.5}$ emission inventory for major sources
- Regional- and local-scale dispersion modeling of base-year (2002) and future-year (2009) emissions
- RACT requirements for local sources that significantly impact $PM_{2.5}$ monitors

Speciated Model Attainment Test

- Attainment test methodology uses ambient $PM_{2.5}$ monitoring data (design values, DV) and model-predicted Relative Reduction Factors (RRF) to estimate future year concentrations
- RRF = Ratio of model-predicted future year concentration to base year concentration (individual RRFs calculated for each $PM_{2.5}$ species)
- Future year concentration = (Base Year DV) x (RRF)
- Total $PM_{2.5}$ is reconstructed from the sum of individual components

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$PM_{2.5}$ Source Apportionment Study

- Analysis of spatial variation and wind direction dependence of $PM_{2.5}$ concentrations, day-of-week and time-of-day temporal variations, carbon isotope analyses, and fenceline monitoring
- Annual $PM_{2.5}$ concentrations at North Birmingham monitor:

  - regional component: 12-14 $\mu g/m^3$
  - urban component: ~2 $\mu g/m^3$
  - local component: ~3 $\mu g/m^3$

Chemical Speciation of $PM_{2.5}$

- Regional component largely sulfate, nitrate, ammonium, and organic carbon (OC)
- Urban component largely OC and elemental carbon (EC) from urban mobile sources and fossil fuel-burning stationary sources
- Local component >80% OC and EC, with some elemental metals (~17%)

Organic and Elemental Carbon

- Overall, $PM_{2.5}$ at North Birmingham monitor ~40% carbonaceous (OC and EC)
- ~70% of carbonaceous $PM_{2.5}$ is OC; ~30% EC

  - OC ~2/3 regional, modern (biogenic) OC and ~1/3 local (urban) fossil OC

  - EC ~1/3 regional, fossil EC and ~2/3 local (urban) fossil EC

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Large Disparity Between Monitored Local Excess $PM_{2.5}$ and Dispersion Modeling Results

- Local-scale dispersion modeling of industrial sources in the vicinity of the NBHM monitor showed large over-estimates of annual $PM_{2.5}$
- Monitoring data showed local excess $PM_{2.5}$ to be >80% carbonaceous
- Local-scale dispersion modeling of major $PM_{2.5}$-emitting sources indicated excess fine particulate at the monitor to be predominantly elemental oxides (foundry, steelmaking, gypsum, and mineral wool facilities)

Large Disparity Between Monitored Local Excess $PM_{2.5}$ and Dispersion Modeling Results (cont.)

- Dispersion model over-predictions due to a number of factors, one of which is the failure of the model to account for the buoyancy of heated, uncaptured fugitive emissions emitted from process melting, hot metal transfer, casting, and pouring operations
- Large disparity in monitored vs. model-predicted $PM_{2.5}$ chemistry suggests sources of carbonaceous PM are not being adequately accounted for in the model

Possible Sources of Local Organic and Elemental Carbon

- Dispersion modeling of Walter Coke and ABC Coke using buoyancy enhancement indicated that the coke industry was *not* a significant contributor (< 0.2 μg/m^3)
- Receptor modeling studies for North Birmingham indicate the overwhelming importance of mobile sources

  - Several major interstate highways (e.g., I-65 and I-20/59) and other major thoroughfares (Highway 31) run within a few kilometers of the monitor

  - Local roads with heavy truck traffic and railways serve the industrial facilities near the monitor

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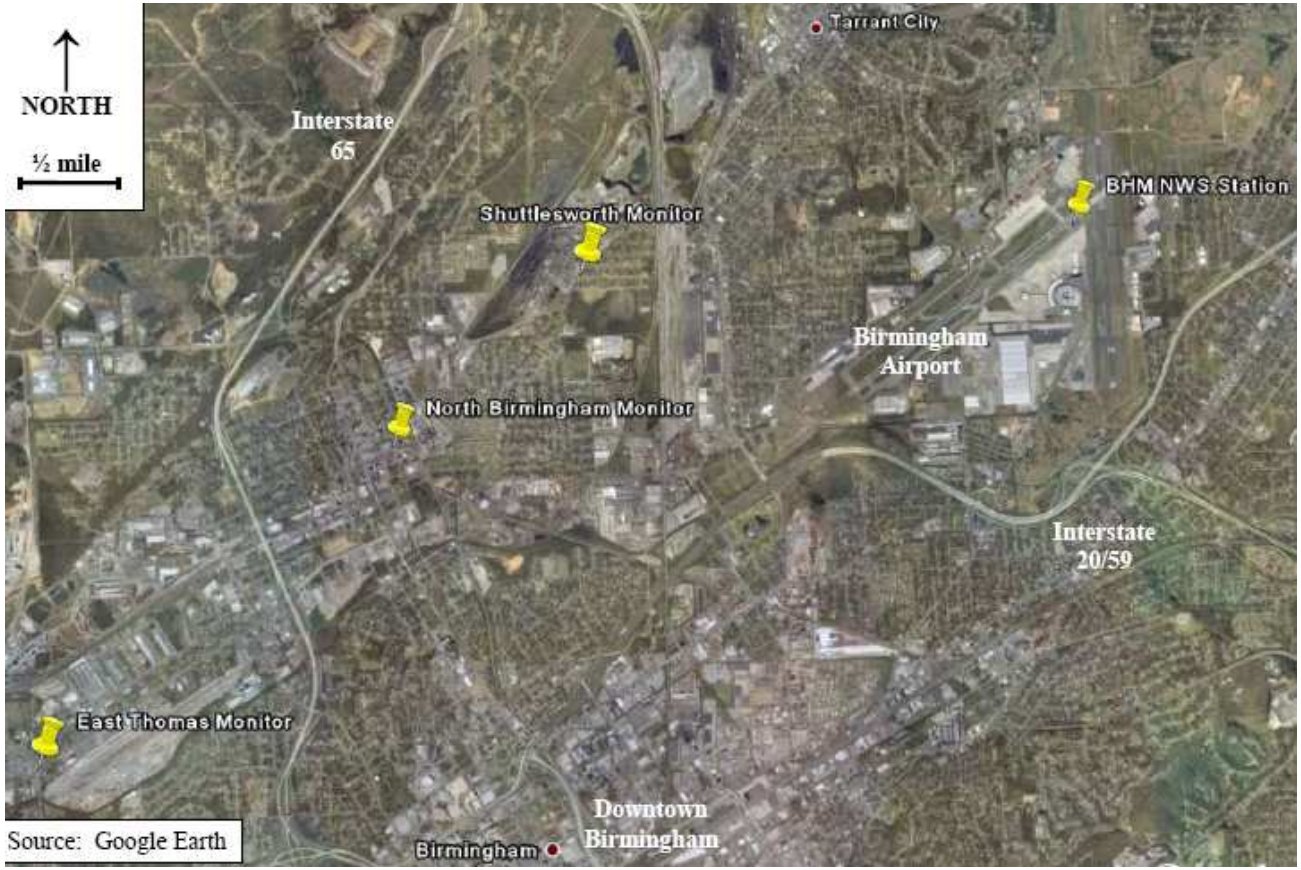
Monitor Locations



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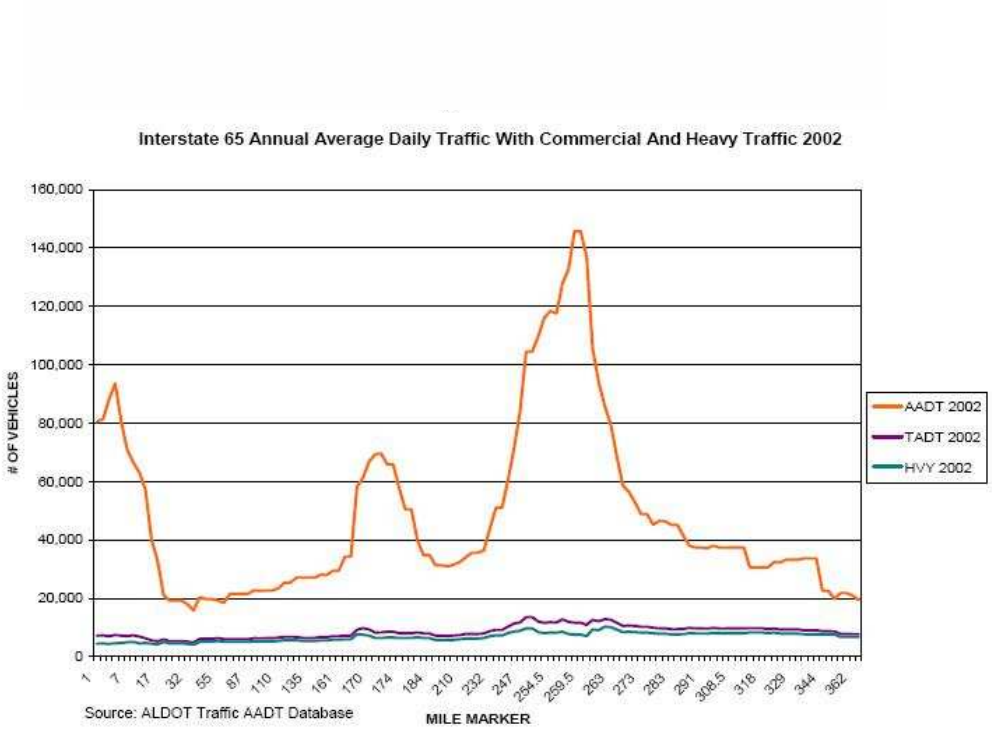
Summary of $PM_{2.5}$ Receptor Modeling Studies Conducted for the North Birmingham Monitor

Study	Estimated Source Contributions at NBHM ($\mu g/m^3$)	
	Motor Vehicles	**Local Industry**
Lee et al., 2007	4.5	3
Zheng et al., 2006 (9 samples only)	5.87 diesel 1.81 gasoline	1.30 (coke plants)
Coutant et al., 2003	6.51	7.27 (coal combustion – regional and urban/local) 0.79 (zinc source) 0.71 (lead source)
Coutant et al., 2007 (draft report)	5.0 $\pm$ 0.4	2.8 $\pm$ 0.3
Baumann et al., 2008	4.5	2.14

Traffic Counts: Birmingham Interstate 65



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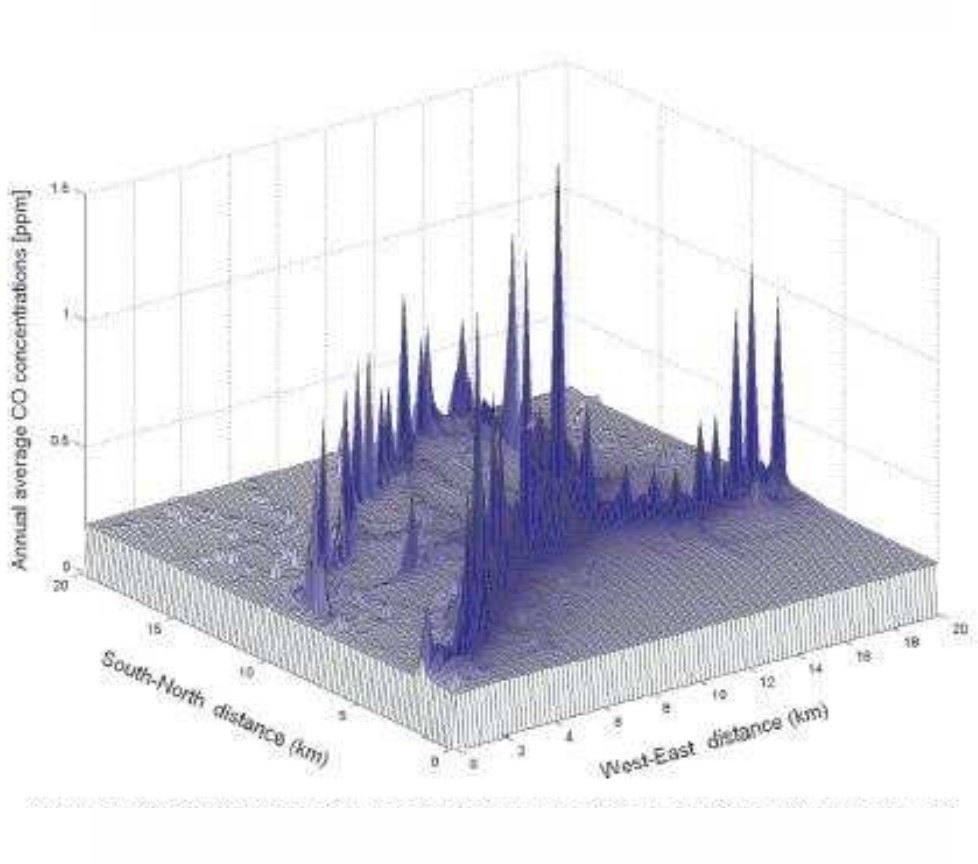
Pollution Gradients Along Major Roadways



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Birmingham $PM_{2.5}$ Attainment Demonstration: Modeling Refinements

- Birmingham Industry Coalition sponsored a mobile source modeling study to address technical concerns about the methodology used for modeling mobile source emissions
- Study involved the application of a local-source dispersion model (AERMOD) instead of a grid model (CMAQ) to better characterize the strong local gradients in mobile source emissions along major highways

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Birmingham $PM_{2.5}$ Attainment Demonstration: Modeling Refinements (cont.)

- Initial modeling results indicated significant mobile source $PM_{2.5}$ impacts limited to a few hundred meters from the roadways
- New EPA mobile source emissions model (MOVES) has recently replaced MOBILE6.2
- Compared to MOBILE6.2, MOVES provides much higher $PM_{2.5}$ emission factors, particularly for low vehicle speeds and low ambient temperatures
- Future plans to remodel major roadways using MOVES emission factors

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Case Study #2: Cleveland $PM_{2.5}$ Source Allocation Study

- One year (2005) of Speciation Trends Network (STN) data for two sites in Cleveland, OH
- 24-hour integrated $PM_{2.5}$ samples every 3rd day
- Analysis for ~50 elements (metals), five ions (sulfate, nitrate, ammonium, sodium, potassium), organic carbon (OC), and elemental carbon (EC)
- U.S. EPA CMB-8.2 Model
- Source profiles for coal combustion, secondary sulfate, metals industry, soil, mobile sources, and biomass burning

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Mobile Source $PM_{2.5}$ Profile

Chemical	Weight %	+/- %		Chemical	Weight %	+/- %
Antimony	0.0206	0.1437		Selenium	0.0018	0.0085
Arsenic	0.0019	0.0197		Tin	0.0174	0.1250
Aluminum	0.0878	0.2117		Titanium	0.0419	0.2298
Barium	0.0357	0.5970		Vanadium	0.0234	0.1005
Bromine	0.0224	0.0150		Silicon	0.3430	0.3707
Cadmium	0.0026	0.0802		Silver	0.0050	0.0762
Calcium	0.2105	0.6048		Zinc	0.2657	0.2492
Chromium	0.0209	0.0403		Strontium	0.0205	0.0860
Cobalt	0.0027	0.0370		Sulfur	1.3358	1.1940
Copper	0.0409	0.0258		Rubidium	0.0005	0.0088
Chlorine	0.0202	0.1949		Potassium	0.0005	0.1006
Gallium	0.0006	0.0298		Yttrium	0.0004	0.0125
Iron	0.6096	0.3545		Sodium	1.5007	2.2472
Lead	0.0279	0.0362		Zirconium	0.0032	0.2260
Manganese	0.0295	0.0202		Ammonium	0.0000	1.3764
Molybdenum	0.0009	0.0266		Sodium Ion	0.3232	0.2649
Nickel	0.0248	0.0572		Potassium Ion	0.1336	0.1684
Magnesium	0.1474	0.2563		Organic Carbon	58.0611	17.8053
Mercury	0.0008	0.0144		Nitrate	0.3664	1.1901
Gold	0.0020	0.0320		Elemental Carbon	37.1657	15.5277
Lanthanum	0.0216	0.7108		Sulfate	2.1563	3.2352
Phosphorus	0.0042	0.0685				

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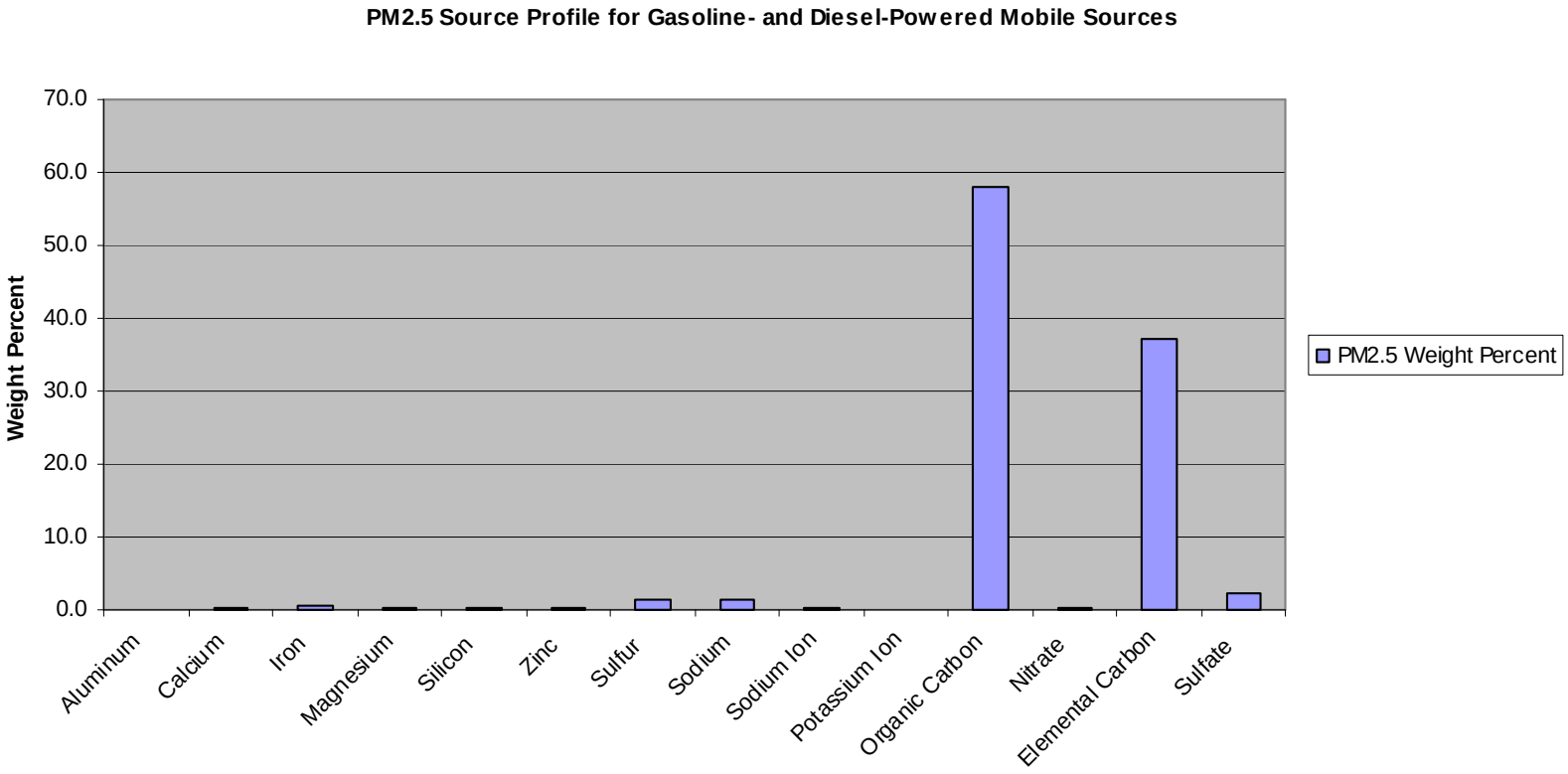
Mobile Source $PM_{2.5}$ Profile



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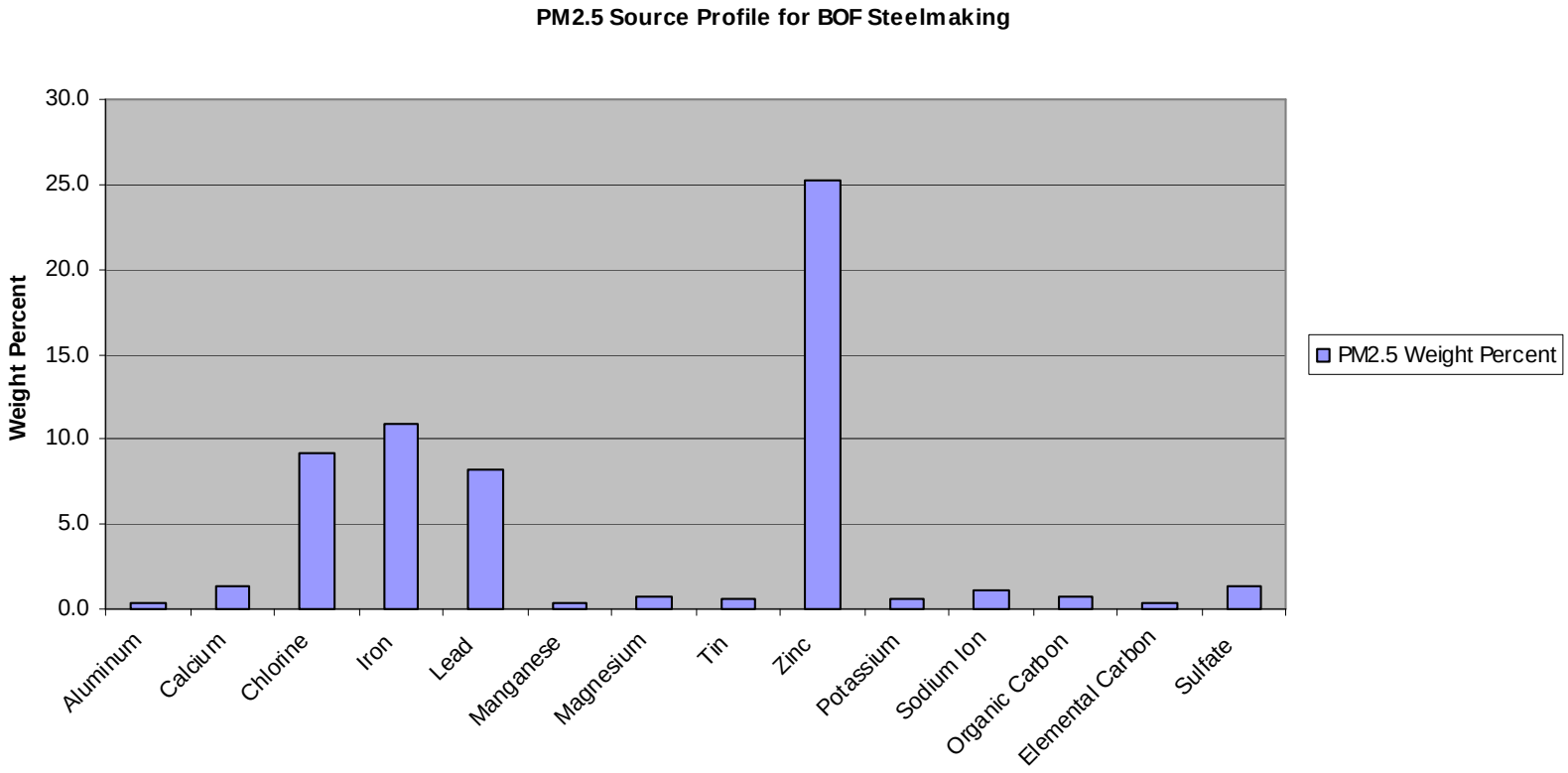
BOF Steelmaking $PM_{2.5}$ Source Profile



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CMB Results: Cleveland $PM_{2.5}$

- Over 95% of total $PM_{2.5}$ mass due to mobile sources, regional sulfate and nitrate, and biomass burning (e.g. residential wood burning)
- Local industry contributed less than 5% of total $PM_{2.5}$ mass

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Air Toxics Studies

- EPA Residual Risk Assessment
- Community monitoring studies in Birmingham, AL and Tonawanda, NY
- EPA air toxics monitoring at schools
- Risk drivers for coke plants include arsenic, benzene, and benzene-soluble organics (BSO), or coke oven emissions

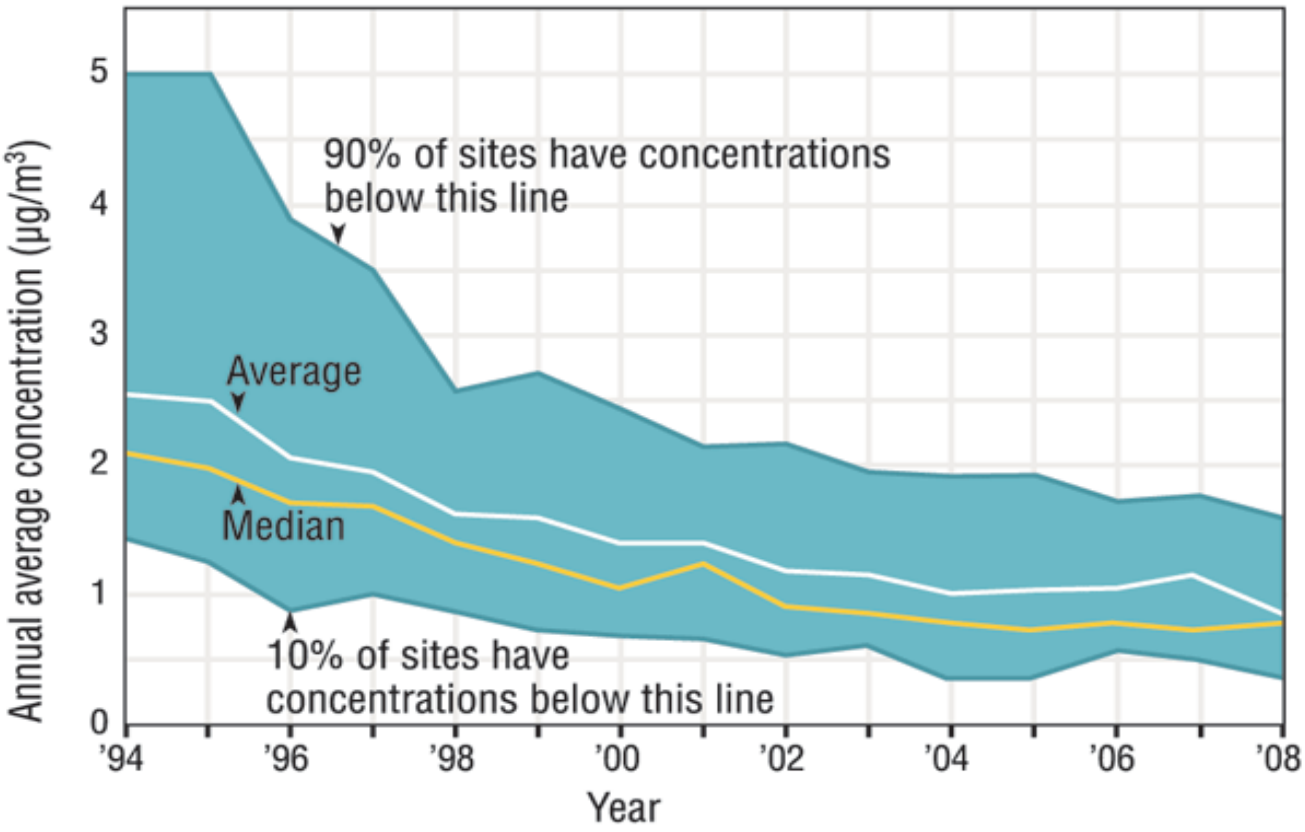
Benzene

- Inhalation Unit Cancer Risk (IUR) = 7.8×10^{-6} $(\mu g/m^3)^{-1}$

  - continuous 70-year exposure to an ambient concentration of 1.0 $\mu g/m^3$ equates to an excess cancer risk of 7.8×10^{-6}

  - AGC = 0.13 $\mu g/m^3$ (concentration at which cancer risk = 1×10^{-6})
- Reference concentration (RfC) = 30 $\mu g/m^3$ (chronic, noncancer)
- Acute dose-response value (AV) = 29 $\mu g/m^3$
- Atmospheric half-life = 5.7 days (relatively unreactive)
- Significant downward trend in U.S. ambient benzene concentrations
- Wide range in personal exposure concentrations

Exhibit 2-43. Ambient benzene concentrations in the U.S., 1994-2008[a]



[a] **Coverage:** 21 monitoring sites nationwide (out of a total of 348 sites measuring benzene in 2008) that have sufficient data to assess benzene trends since 1994.

Data source: *U.S. EPA, 2009*

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Case Study #3: Birmingham Air Toxics Study

- One year of monitoring at four sites (July 2005 – June 2006)
- 24-hour samples; 31 samples per site
- Over 100 metals, volatiles, semi-volatiles, and carbonyl species
- Risk characterization for chronic exposure (cancer and non-cancer) and for acute exposure

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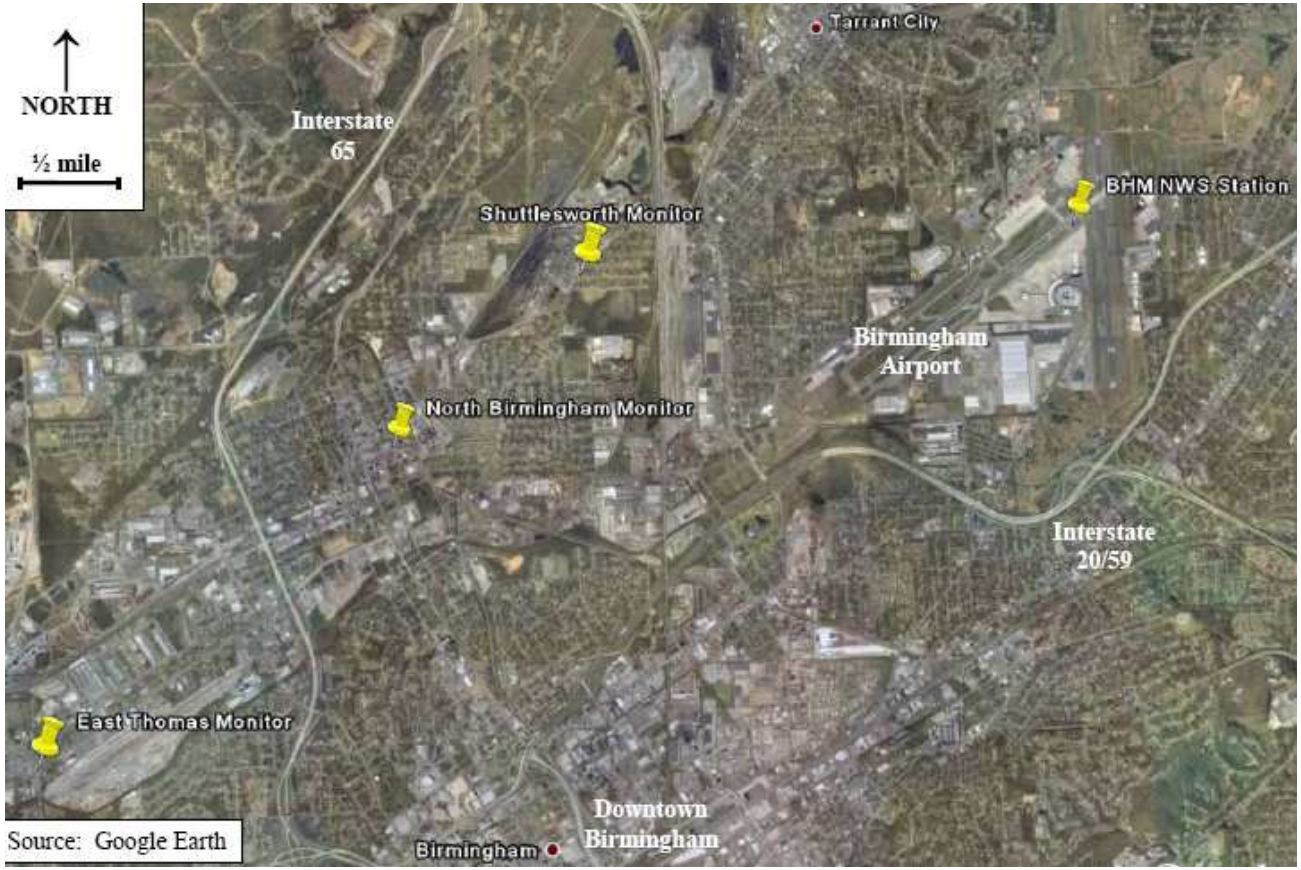
Monitor Locations



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Birmingham Air Toxics Study: Major Results

- Potential risk drivers for chronic cancer risk at all four sites: 1,3-butadiene, acetaldehyde, arsenic, benzene, carbon tetrachloride, and p-dichlorobenzene
- Potential hazard drivers for chronic non-cancer hazards at all four sites: acetaldehyde, acetonitrile, acrolein, and manganese
- Naphthalene and benzo(a)pyrene potential risk drivers at North Birmingham and Shuttlesworth
- Acute hazard quotient threshold exceeded only once (benzene at Shuttlesworth)

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Birmingham Air Toxics Study: Major Results (cont.)

- All monitors in the BATS monitoring program exceeded a 1 x 10^{-6} lifetime cancer risk for cumulative risk and for some chemicals individually
- Cumulative cancer risks ranged from 3.36 x 10^{-5} at Providence to a high of 1.66 x 10^{-4} at Shuttlesworth
- Highest risk for a single pollutant was 6.40 x 10^{-5} for benzene at Shuttlesworth

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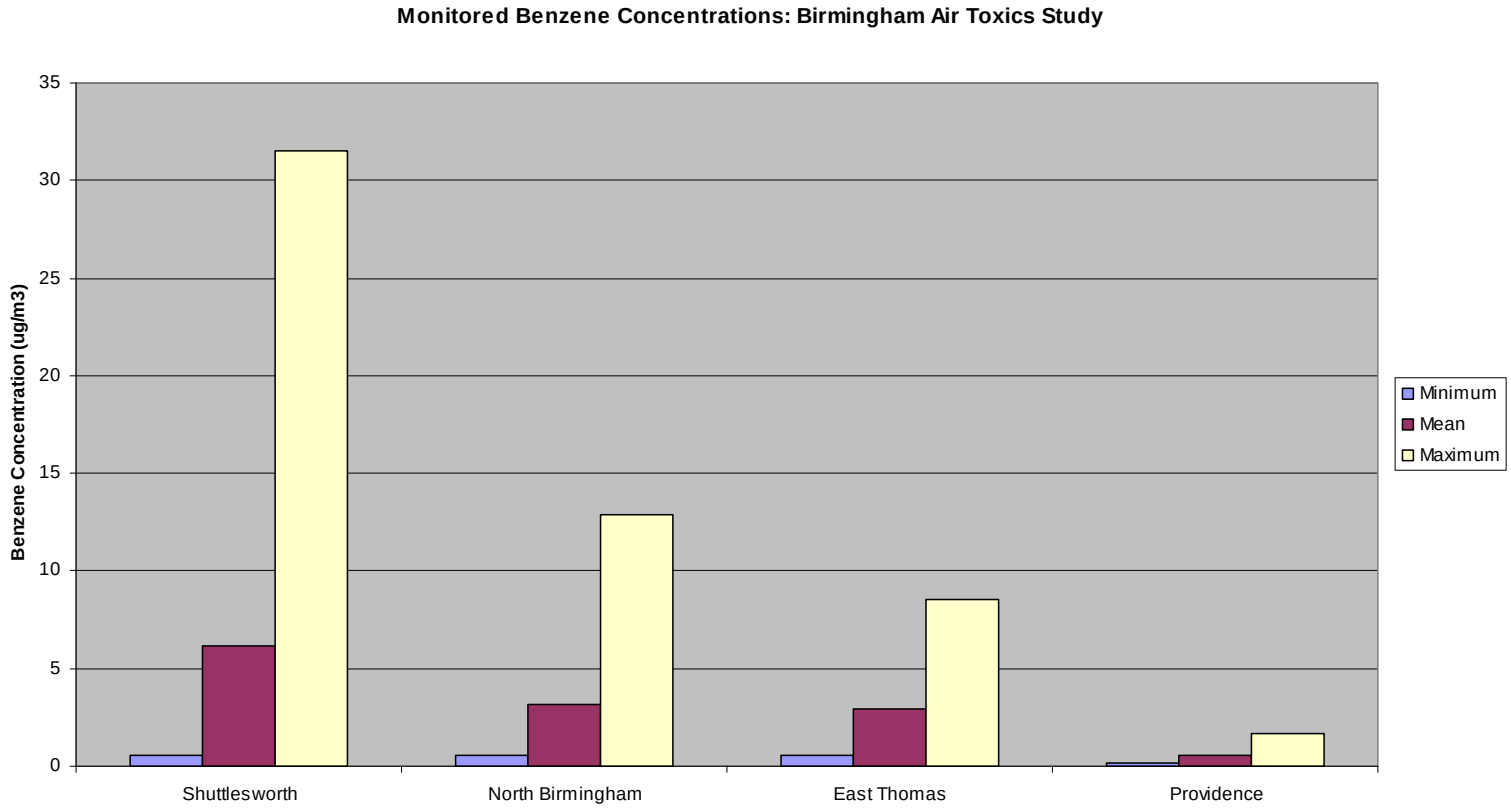
Monitored Benzene Concentrations: Birmingham Air Toxics Study



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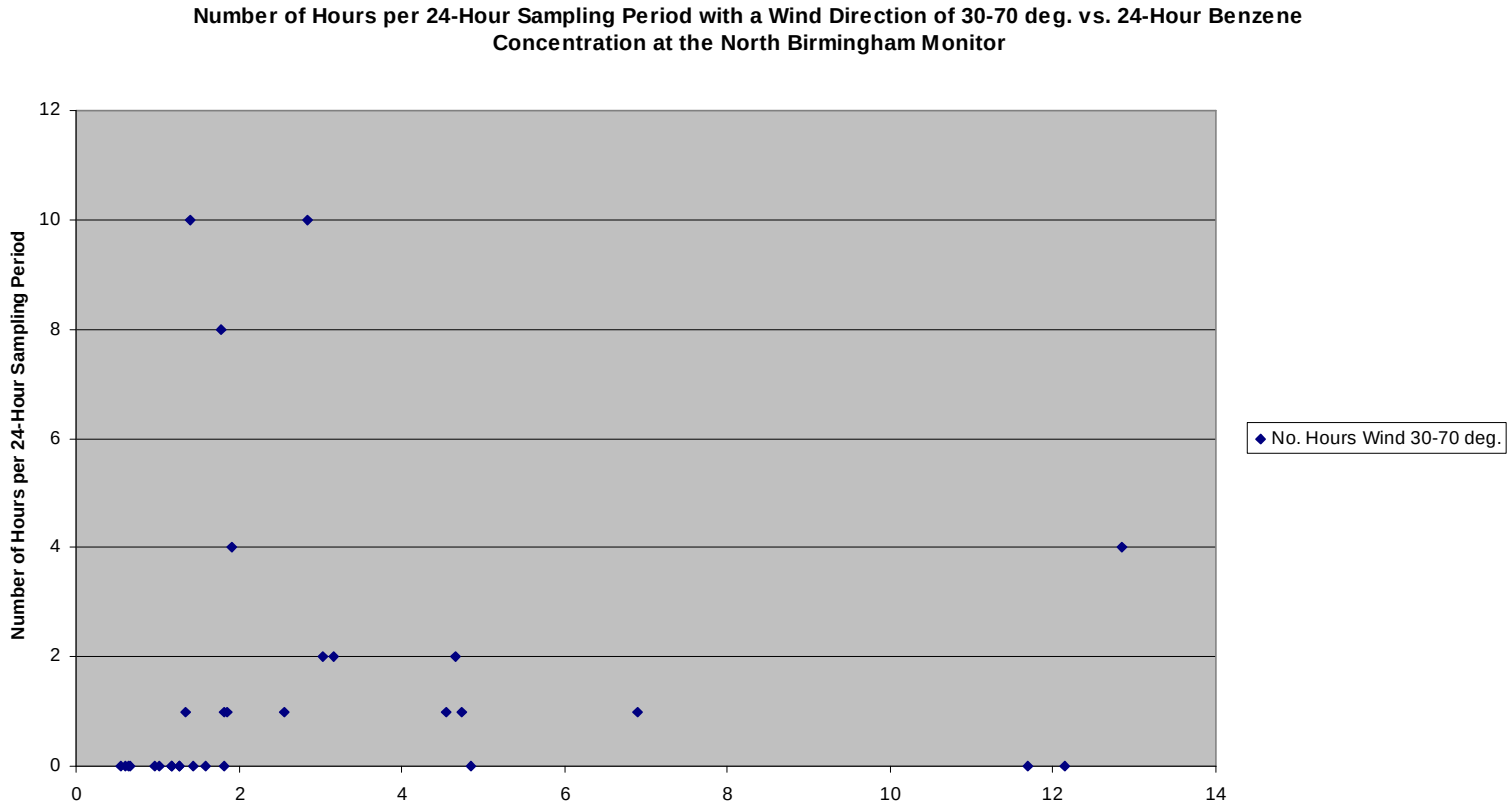
Analysis of Potential Coke Plant Impact on Monitored 24-Hour Benzene Concentrations at the North Birmingham Monitor



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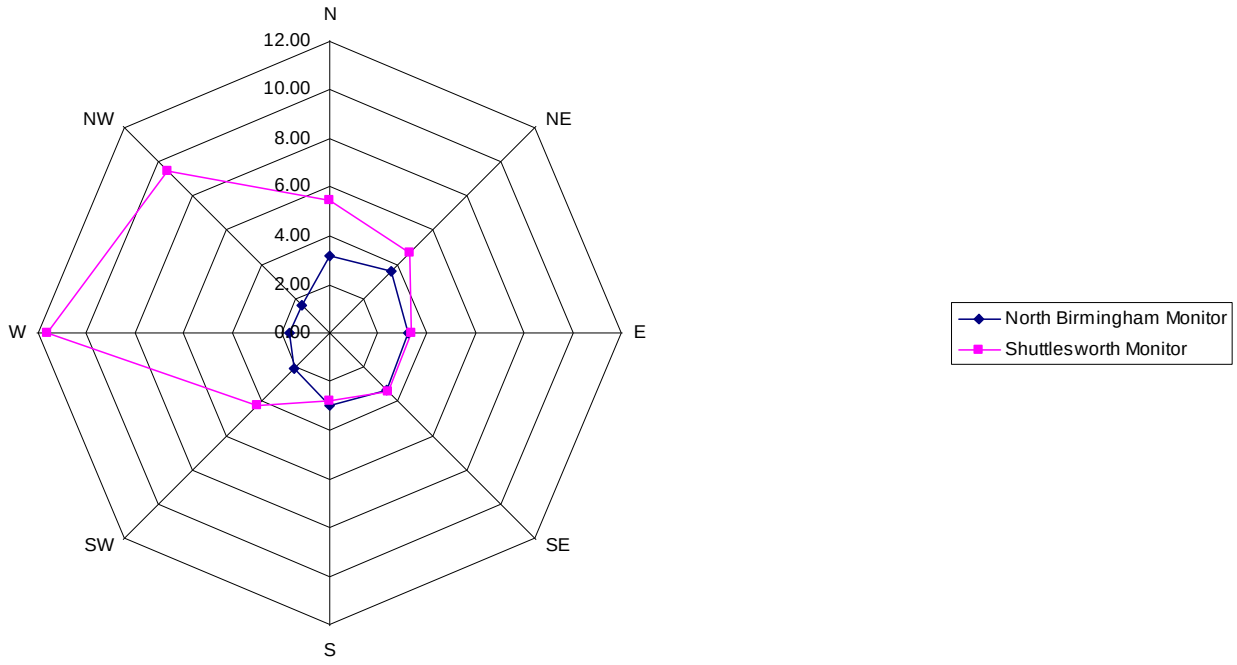
Pollution Rose for Benzene at the North Birmingham and Shuttlesworth Monitors

Average Benzene Concentration (ug/m3) at the North Birmingham and Shuttlesworth Monitors as a Function of Wind Direction (2005-2006 Birmingham Air toxics Study)



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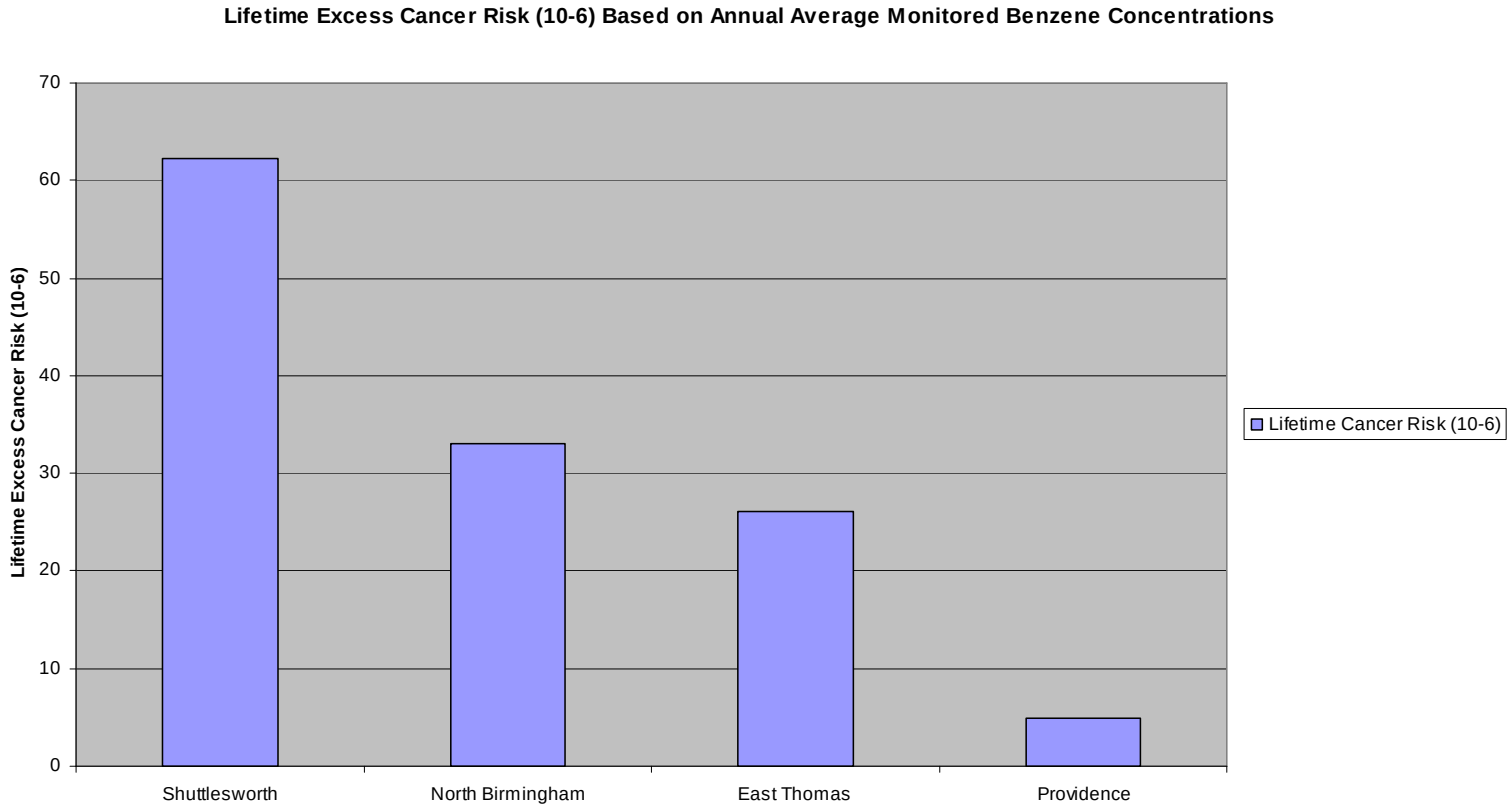
Lifetime Excess Cancer Risk Based on Annual Average Monitored Benzene Concentrations in Birmingham



USEPA Comprehensive Residual Risk Report to Congress (1999)

- 1×10^{-4} threshold selected as maximum individual lifetime cancer risk (upper end of acceptability range)
- 1×10^{-6} threshold chosen to provide an ample margin of safety
- Recommended that only voluntary actions be taken when residual risks are between 1×10^{-6} and 1×10^{-4}

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Birmingham Air Toxics Study: Follow-Up Activities

- JCDH, in concert with USEPA, to continue to address air toxics concerns for those pollutants with elevated risk/hazard levels, by:

  - assuring compliance with and enforcing the numerous MACT standards that apply to 80+ industrial source categories, including coke oven by-products plants, steel mills, and surface-coating operations, etc. and

  - assuring compliance with and enforcing the numerous GACT (Generally Achievable Control Technology) standards that apply to numerous area source categories, including dry cleaners, gasoline stations, autobody refinishing operations, etc.

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Birmingham Air Toxics Study: Follow-Up Activities (cont.)

"Most of the chemicals that are risk drivers are quite ubiquitous in nature, emanating from a variety of sources, including industrial, area, and, most notably, mobiles sources, that making direct control of most sources implausible. The one exception is the Shuttlesworth site, for which the Department is working with a very proximate coke by-products plant to reduce concentrations of several chemicals that are risk drivers."

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Jefferson County, AL 2002 HAP Emissions Estimates (NEI)

Pollutant	Total Emissions (lbs/yr)	Fractional Contributions to Total (%)			
		Major Sources[1]	Nonpoint Sources[2]	Onroad Mobile Sources[3]	Nonroad Mobile Sources[4]
Benzene	1,786,560	2.0	21.7	13.3	63.0
Toluene	4,247,679	0.4	18.7	13.4	67.5
Ethylbenzene	628,794	4.0	5.2	23.1	67.6
Xylenes	3,130,164	12.9	17.4	18.3	51.4
Styrene	128,119	23.7	6.3	5.9	64.2
Acrolein	32,280	9.6	13.4	18.3	58.6
Formaldehyde	626,487	7.9	9.6	22.8	59.6
Manganese Compounds	19,861	99.7	0.2	0.0	0.1
Lead Compounds	32,792	94.2	0.1	5.7	0.0
Naphthalene	63,620	48.7	8.1	9.0	34.3
15 PAH	5,662	25.7	7.7	23.2	43.4

Notes:

(1) Major sources include stationary sources having $\geq$ 10 TPY of a single HAP and $\geq$ 25 TPY of all HAPs.

(2) Nonpoint sources include area sources (< 10 TPY of a single HAP and < 25 TPY of all HAPs, such as dry cleaners, gas stations, autobody refinishing shops, etc.) and diffuse processes such as wildfires and prescribed burning.

(3) Onroad mobile sources include all mobile vehicles on public roads.

(4) Nonroad sources include 2- and 4-stroke diesel engines, nonroad vehicles, aircraft, locomotives, commercial marine vessels, etc.

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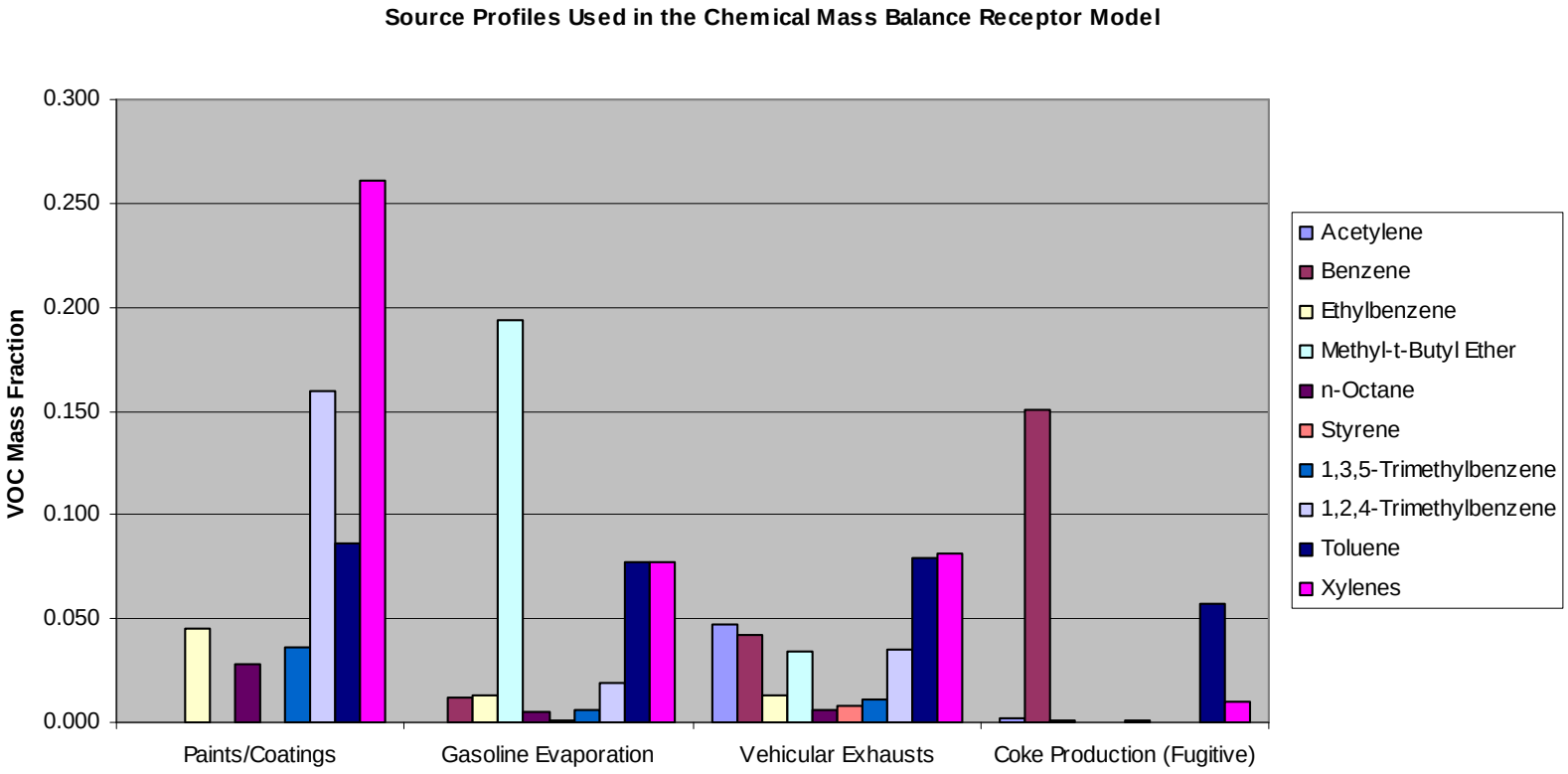
CMB Volatile HAP Source Profiles



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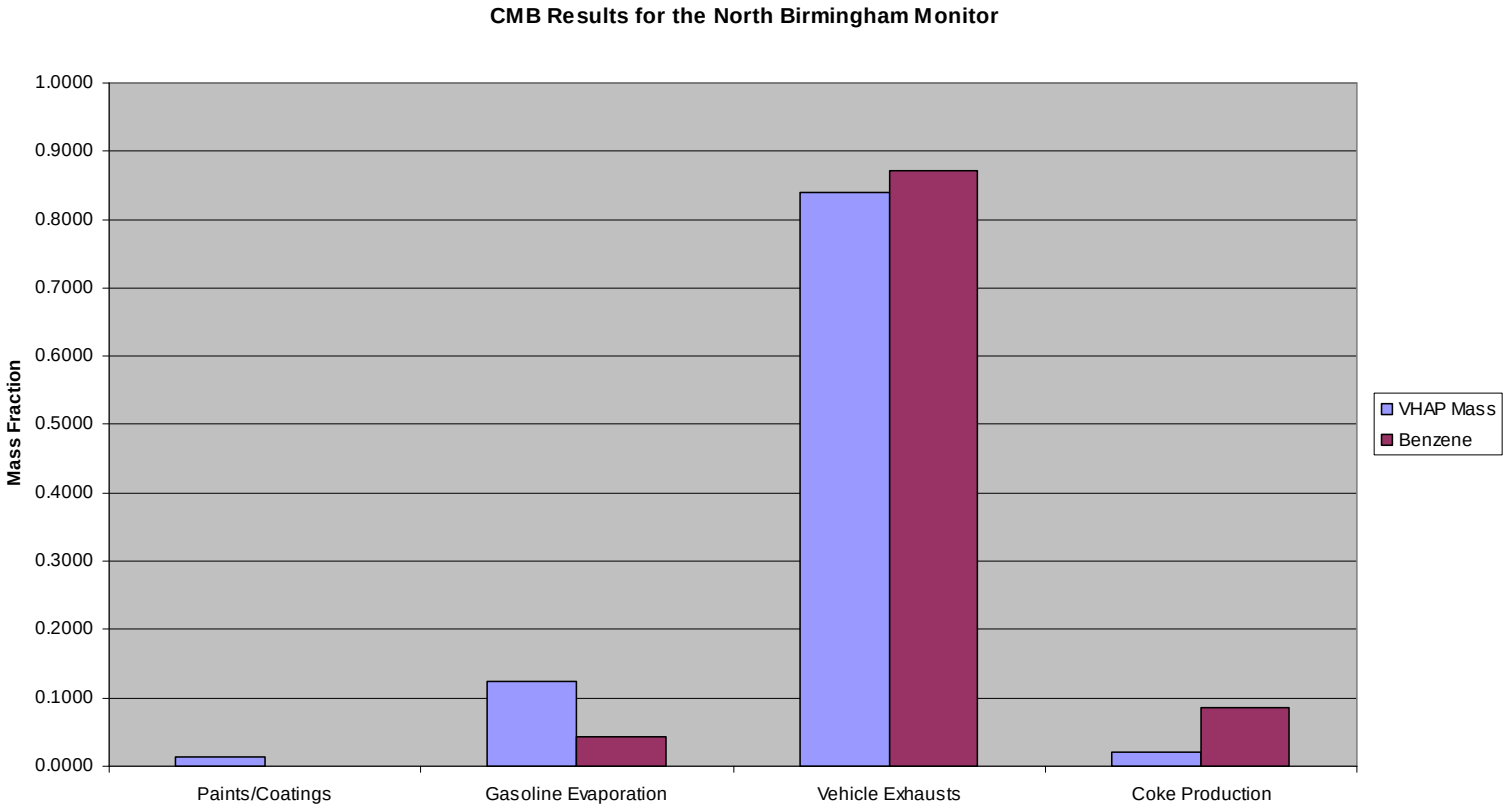
CMB Results for North Birmingham Monitor



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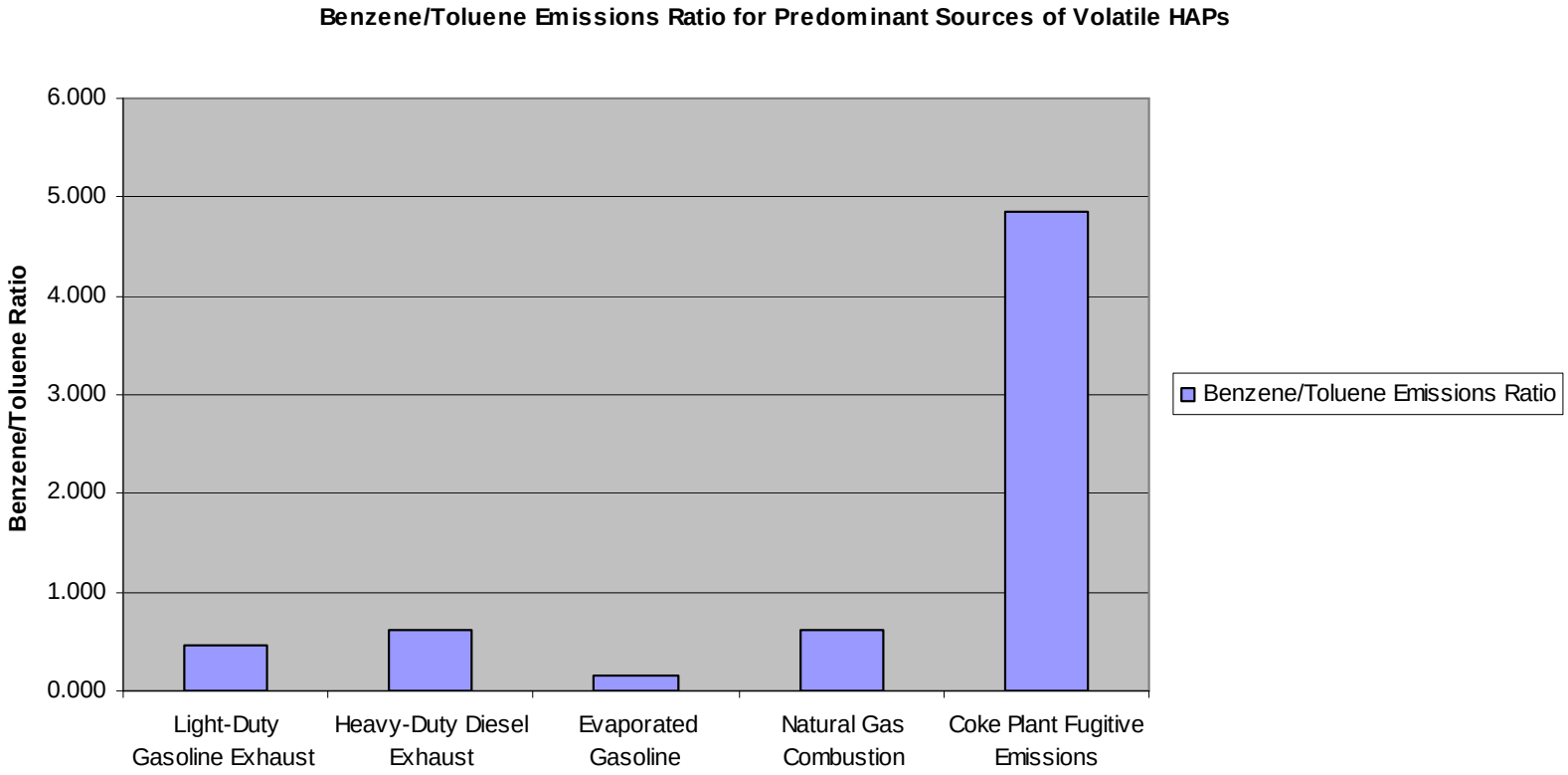
Benzene/Toluene Emissions Ratio



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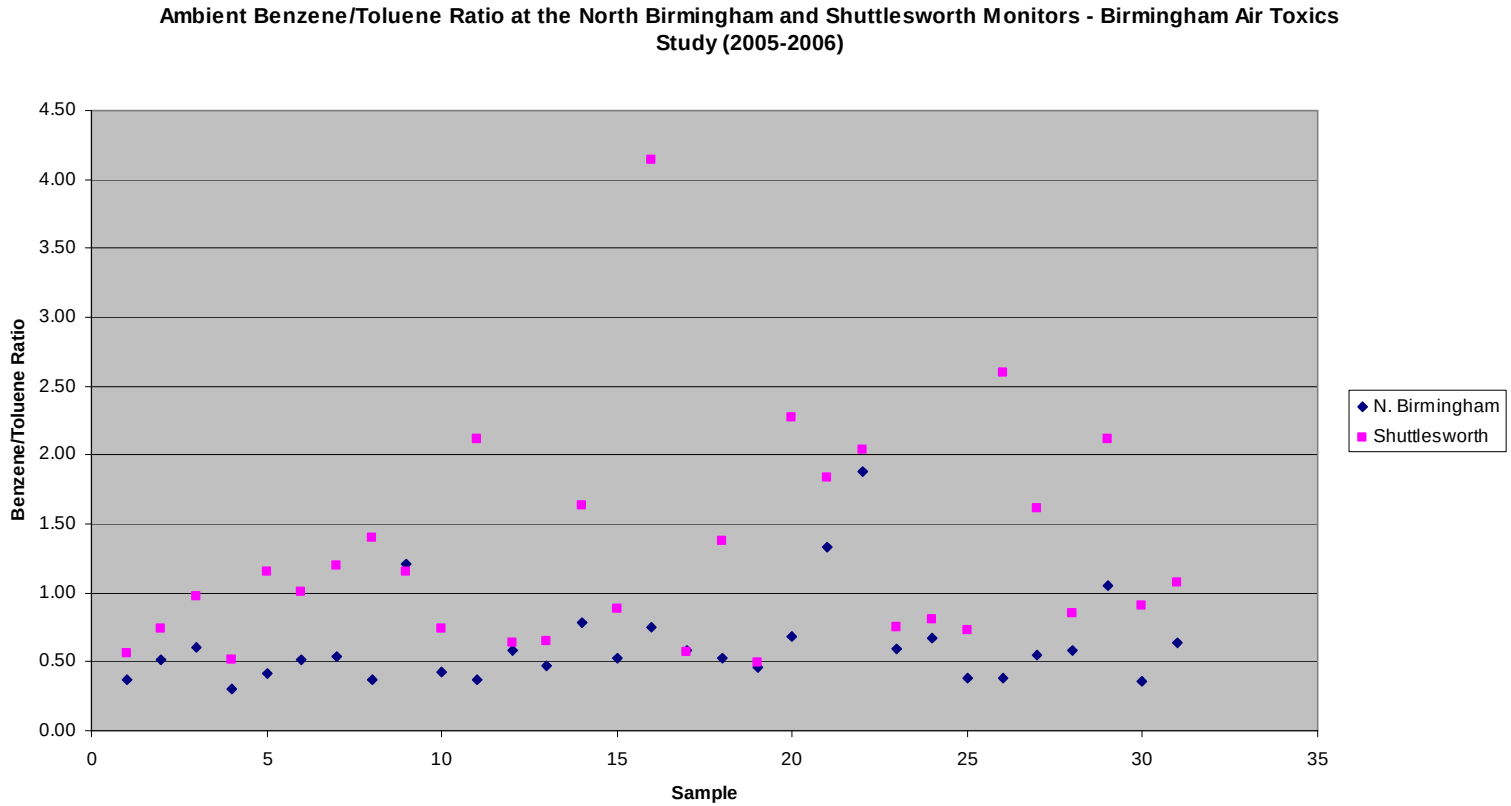
Benzene/Toluene Ratios: Birmingham Air Toxics Study



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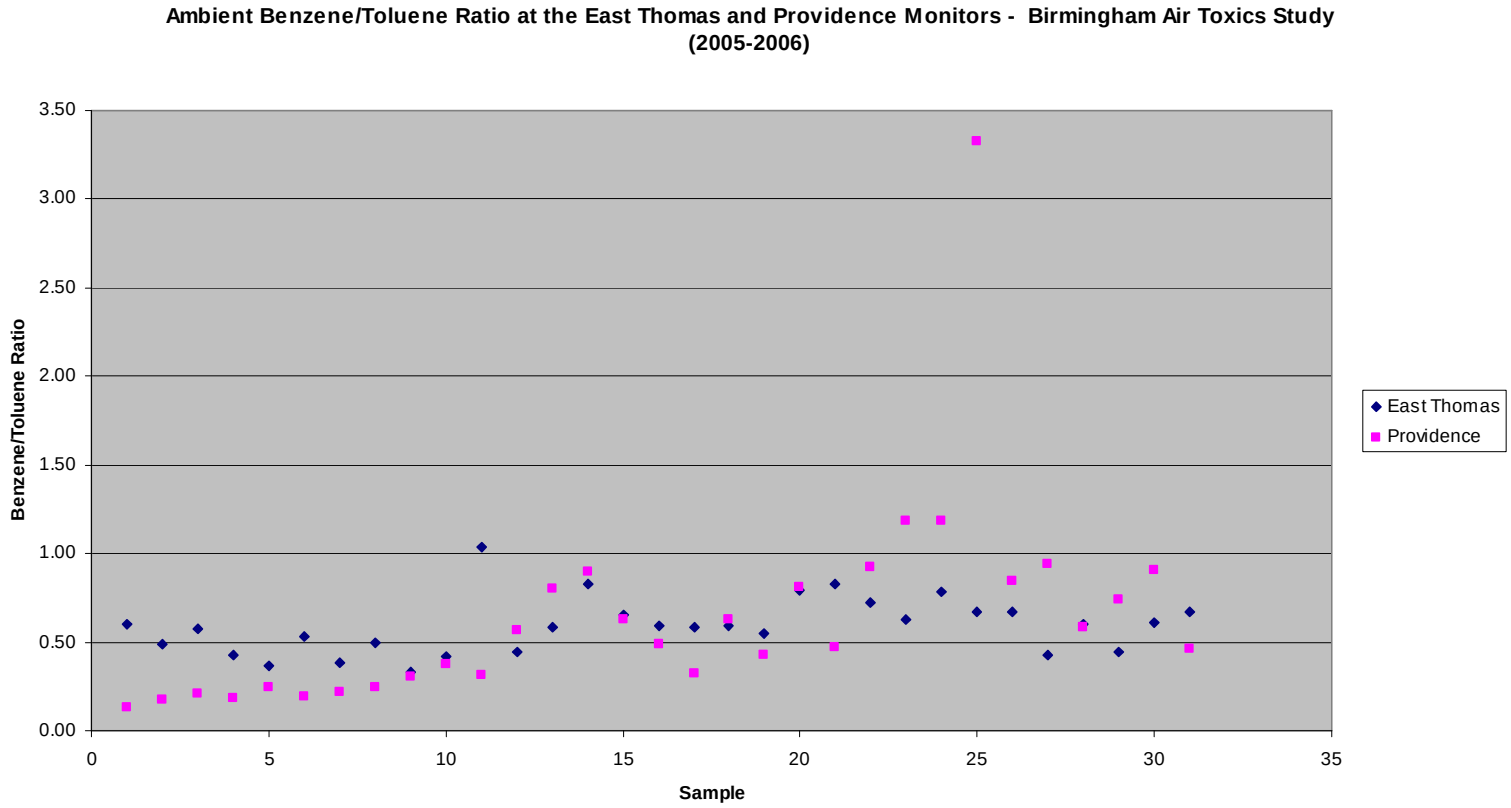
Benzene/Toluene Ratios: Birmingham Air Toxics Study



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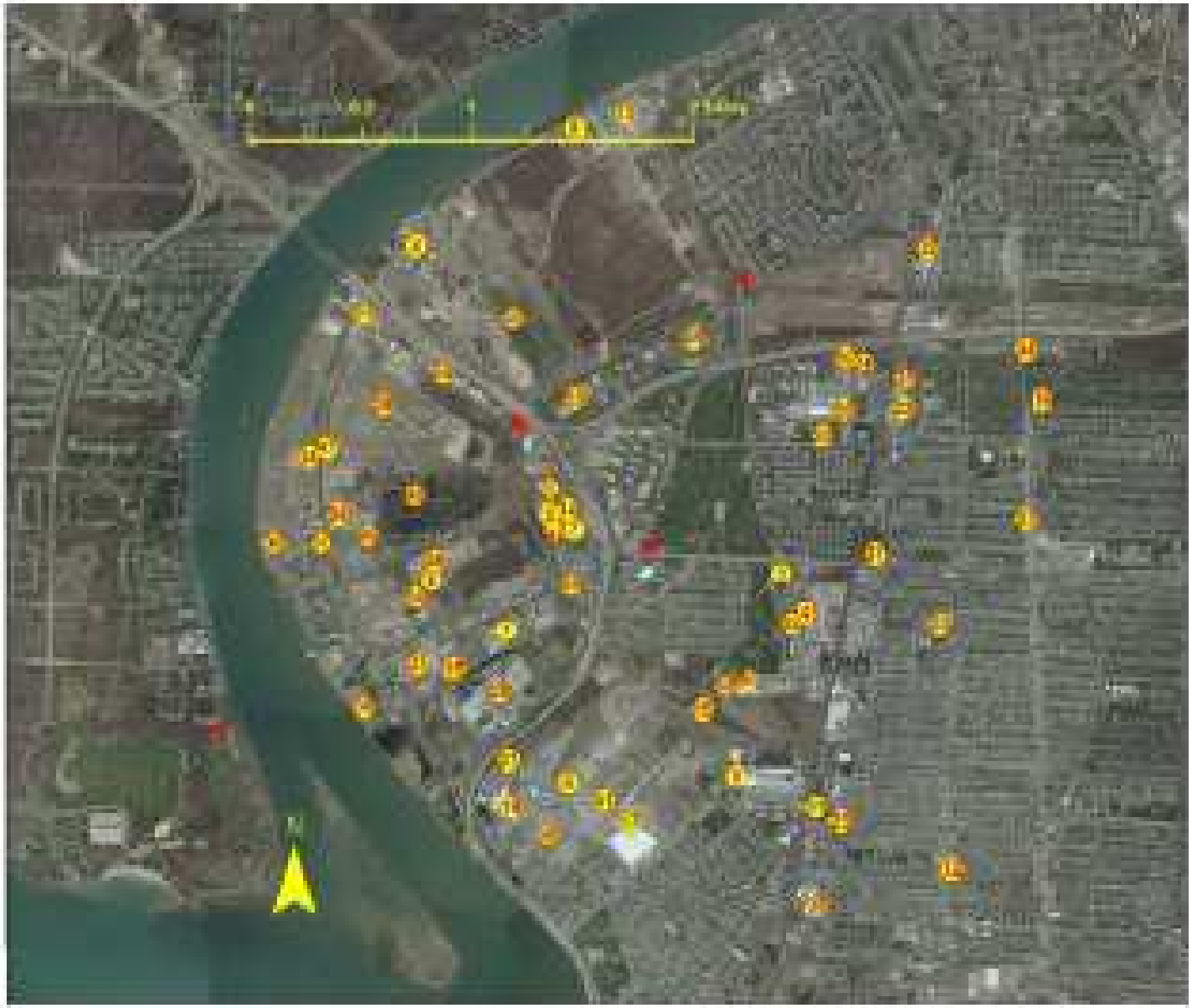
Case Study #4: Tonawanda Community Air Quality Study

- Monitoring, modeling, and inhalation risk assessment
- Four monitors (one background upwind of industrial sources; three downwind perimeter industrial monitors)
- 24-hour samples for 56 toxic pollutants, $PM_{2.5}$, SO_2, and CO
- One-in-six day monitoring schedule (July 2007 – June 2008)



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Motivating Basis for the Study

- Community odor complaints (Clean Air Coalition of Western New York)
- Elevated short-term benzene concentrations sampled by a local community group and NYSDEC
- 1999 National-Scale Air Toxics Assessment and Coke Oven Residual Risk Assessment for Arsenic, Benzene, and BSO exposure indicated potential for elevated cancer risk ($> 10^{-6}$)

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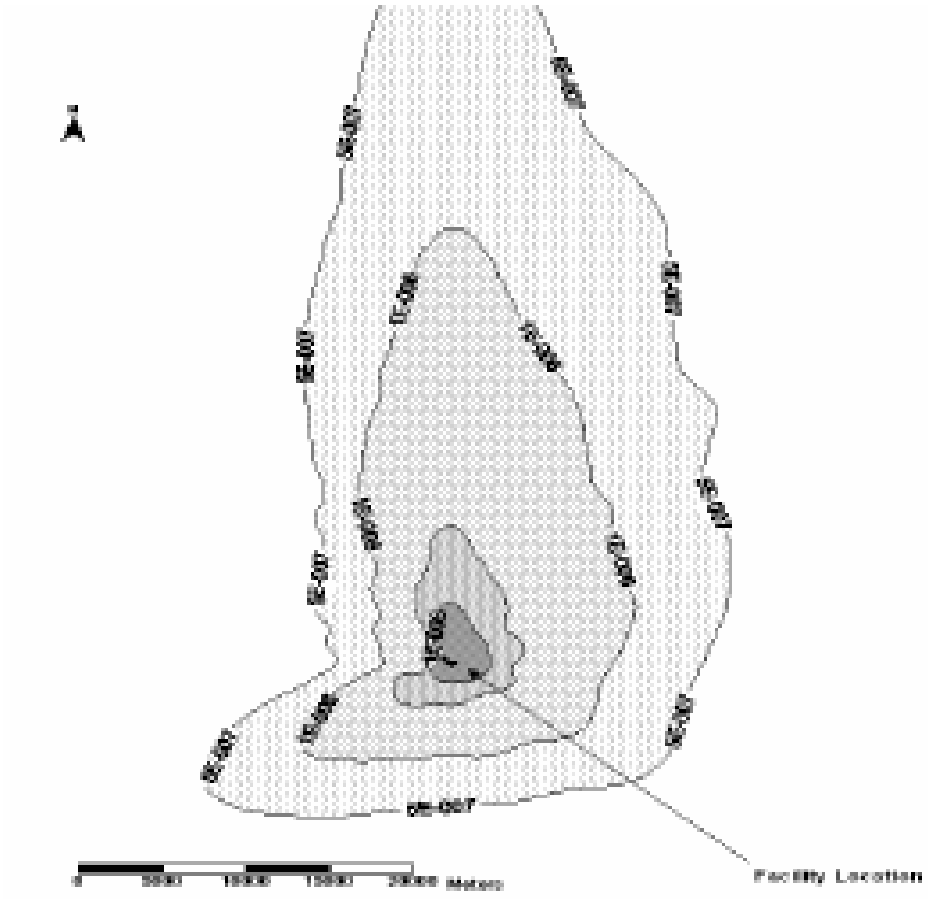
Coke Oven MACT Residual Risk Study: Cancer Risk Isopleths Around Tonawanda Coke



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Tonawanda Community Air Quality Study Results

- Grand Island Boulevard Industrial (GIBI) site had significantly elevated concentrations of benzene and formaldehyde
- Benzene showed strongest wind directionality, with highest concentrations at GIBI when Tonawanda Coke was upwind of monitor
- Formaldehyde, acetaldehyde, and acrolein showed weaker wind directionality and were attributed to local area and mobile sources (general products of combustion)
- 1,3-butadiene, acetaldehyde, benzene, carbon tetrachloride, and formaldehyde exceeded 10^{-6} cancer risk screening level
- Acrolein exceeded non-cancer hazard quotient

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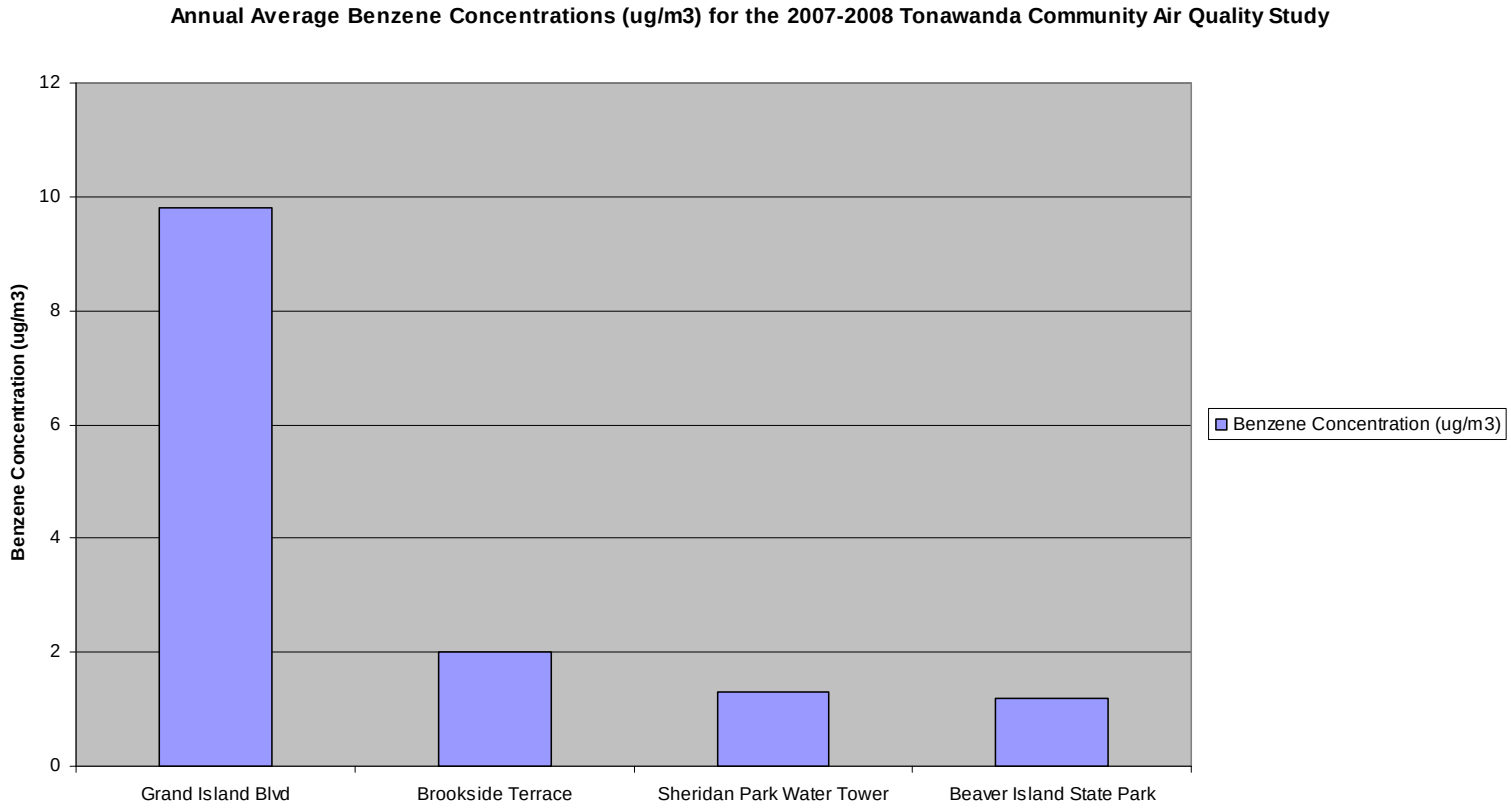
Monitored Benzene Concentrations: Tonawanda Community Air Quality Study



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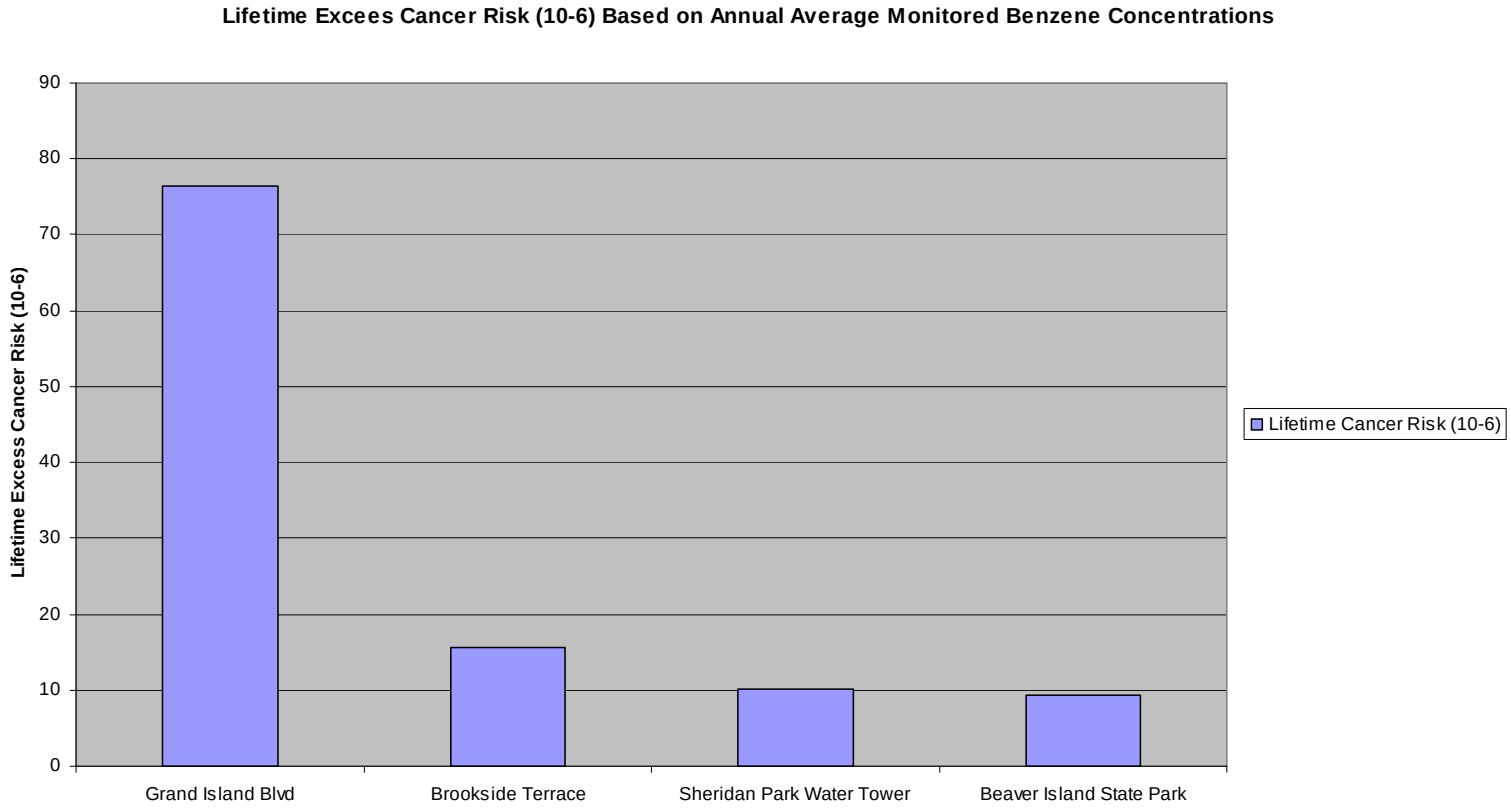
Lifetime Excess Cancer Risk Based on Annual Average Monitored Benzene Concentrations in Tonawanda



Comparison of 2005 U.S. Air Monitoring Concentrations and the Tonawanda Study Sites

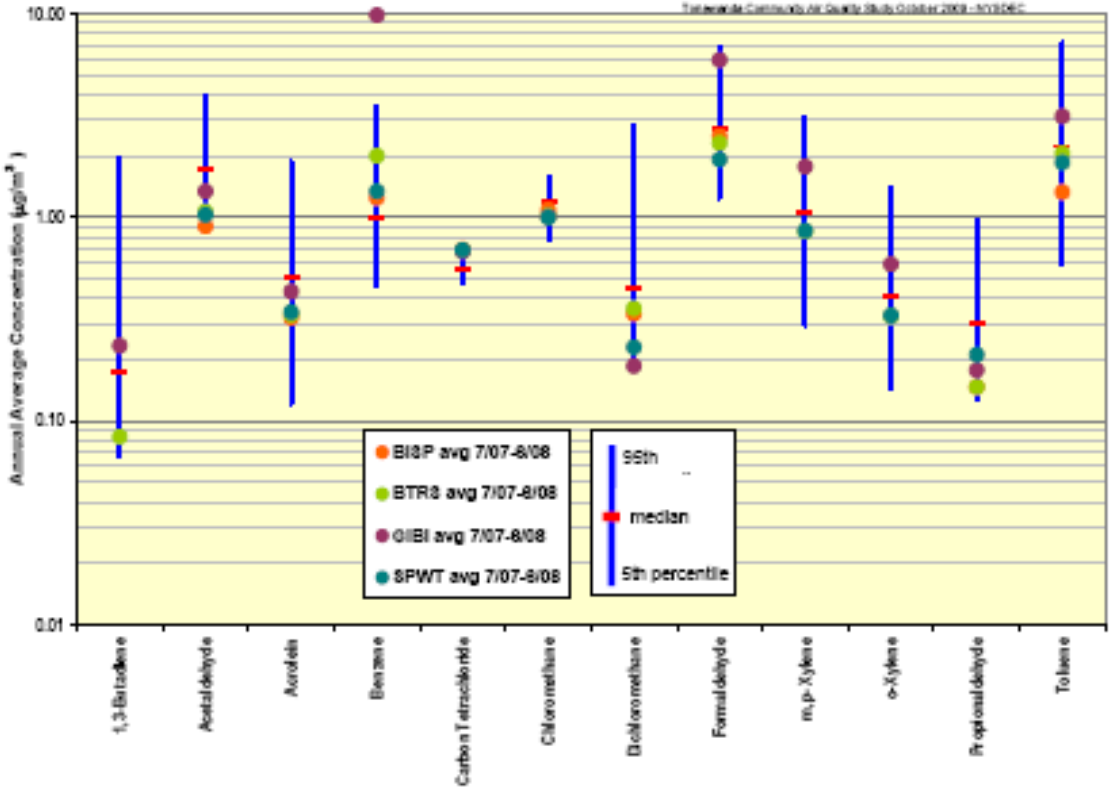


Figure 7.4 Comparison of US (2005) Air Monitoring Concentrations and Tonawanda Study Sites

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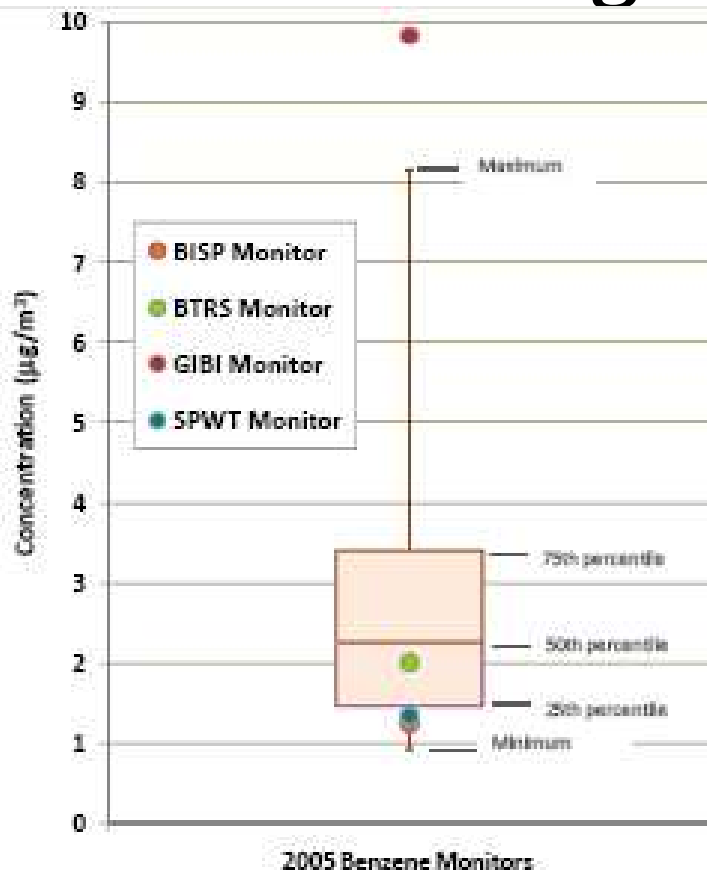
Comparison of 2005 Annual Average Benzene Concentrations for Monitors Near Benzene-Emitting Facilities



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Benzene Pollution Roses: Tonawanda Community Air Quality Study

Figure 7.14. Benzene TW Pollution Roses

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Acrolein Pollution Roses: Tonawanda Community Air Quality Study

Figure 7.33. Acrolein TW Pollution Roses

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Emission Sources for HAPs Exceeding AGC Levels

Pollutant	Atmos. Half-Life (hrs.)	2002 NATA Emissions (TPY)	Mobile Source Emissions (% Total)	Industrial Sources
1,3-Butadiene	1-9	85	99.3%	Valley Retread Corp. Tonawanda Goodyear Tonawanda Coke
Acetaldehyde	12-24	96	96%	3M Tonawanda Tonawanda Goodyear Huntley Power Plant
Acrolein	-	15.3	83%	3M Tonawanda
Benzene	5.7 days	897	77%	Tonawanda Coke Huntley Power Plant NOCO Energy Tonawanda Sunoco
Carbon Tetrachloride	-	< 1 lb/yr	0	None
Formaldehyde	-	270	95%	Indeck Yerkes Huntley Power Plant Unifrax Inc.

Study Results (cont.)

- Local-scale dispersion modeling (AERMOD) for Tonawanda Coke indicated a factor of 3 underprediction of monitored benzene concentrations at the GIBI site, suggesting that benzene emissions from Tonawanda Coke are underestimated (under further investigation by NYSDEC and USEPA)
- Modeling *did not* account for enhanced buoyancy of coke battery emissions and over-predicted PAH concentrations by a factor ~4

Study Results (cont.)

- Based on NYSDEC's assessment of monitored data and modeling results, the maximum individual cancer risk due to emissions from Tonawanda Coke exceed 10 in-one-million for the nine census tract study area, and specific neighborhoods exceed the 100 in-one-million cancer risk level

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Tonawanda Community Air Quality Study: Follow-Up Activities

- Enhanced community monitoring:

  - additional year of VOC, carbonyl, and $PM_{2.5}$ monitoring at the GIBI and BTRS monitors

  - continuous automated benzene, toluene, ethylbenzene, and xylene monitoring at the GIBI monitor (15-minute samples)

  - high volume sampler for PAH measurements at GIBI (24-hour samples)

Tonawanda Community Air Quality Study: Follow-Up Activities (cont.)

- Increased compliance inspections, particularly for benzene-emitting sources (Tonawanda Coke, Sunoco and NOCO Energy Petroleum Distribution facilities)
- Voluntary emission reductions at Tonawanda Coke:
  - emissions from light oil storage and loading (benzene emission reduction ~ 1,700 lbs/yr)
  - emissions from the ammonia still (benzene emission reduction ~3,000 lbs/yr)

Case Study #5: EPA School Air Toxics Monitoring Initiative

- EPA monitored at 62 schools in 22 states
- Daily samples every 6 days over a 10+ week period for ~100 metals, volatiles, semi-volatiles, and carbonyl species
- School selection based on modeling of point, area, and mobile sources using National Air Toxics Assessment (NATA) dispersion model and National Emission Inventory for 2002
- Four schools (Riggins, Tarrant Elementary, North Birmingham Elementary, Lewis Elementary) in the North Birmingham Industrial area

EPA School Air Toxics Monitoring Initiative (cont.)

- EPA to release an abbreviated health risk assessment for each school within about 4-6 months after sampling
- Health risk assessment to be based on monitored concentrations, local meteorology, and level of industrial activity during monitoring
- EPA developing a methodology to estimate chronic health effects (e.g., cancer) from only 2 months of monitoring data

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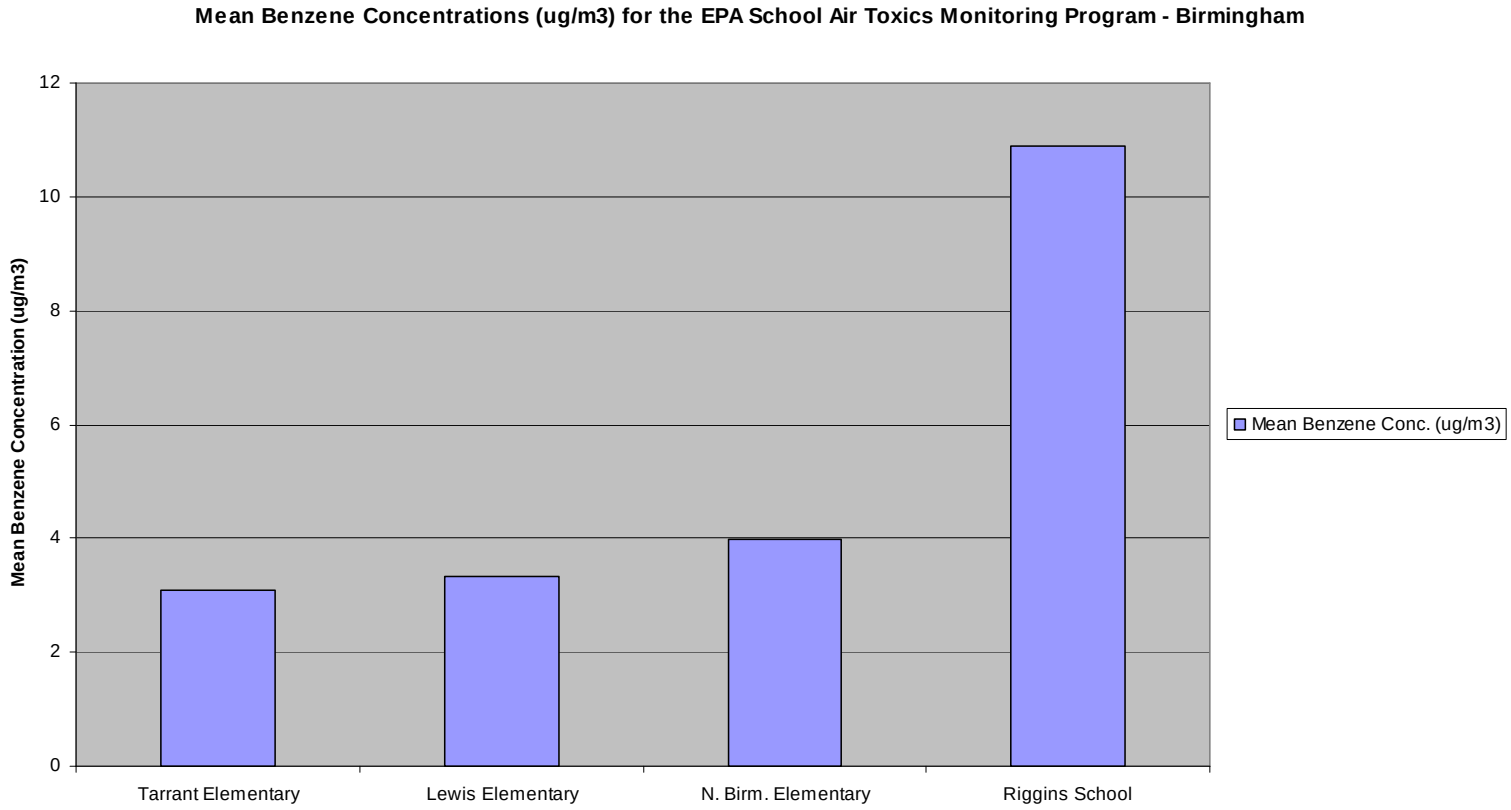
Mean Benzene Concentrations: EPA School Monitoring Initiative



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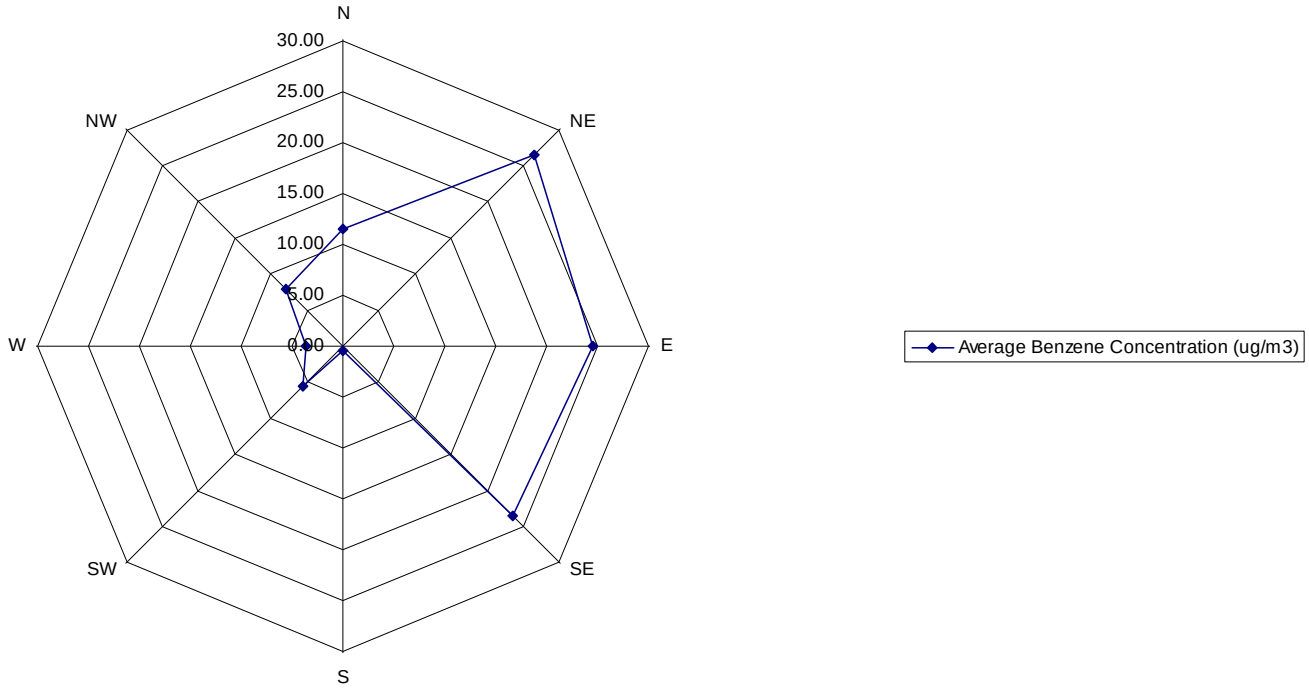
Benzene Pollution Rose: Riggins School



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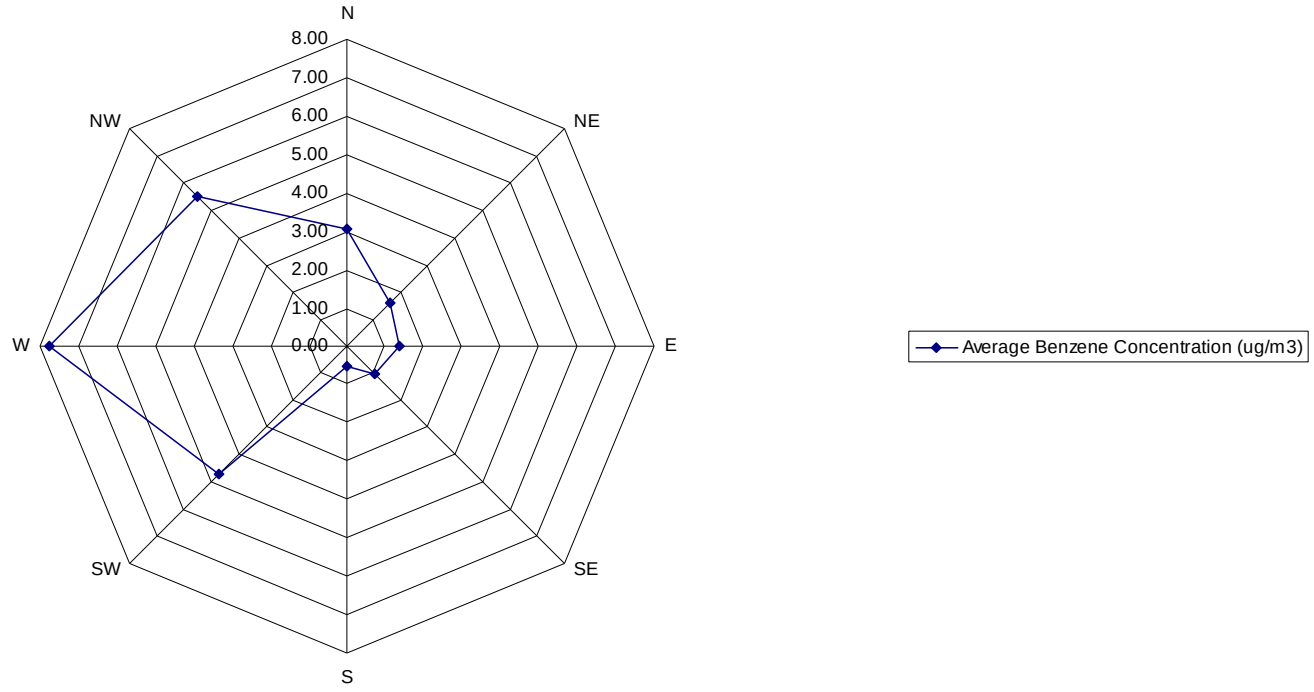
Benzene Pollution Rose: Tarrant Elementary School

Average Benzene Concentration (ug/m3) at Tarrant Elementary School as a Function of Wind Direction



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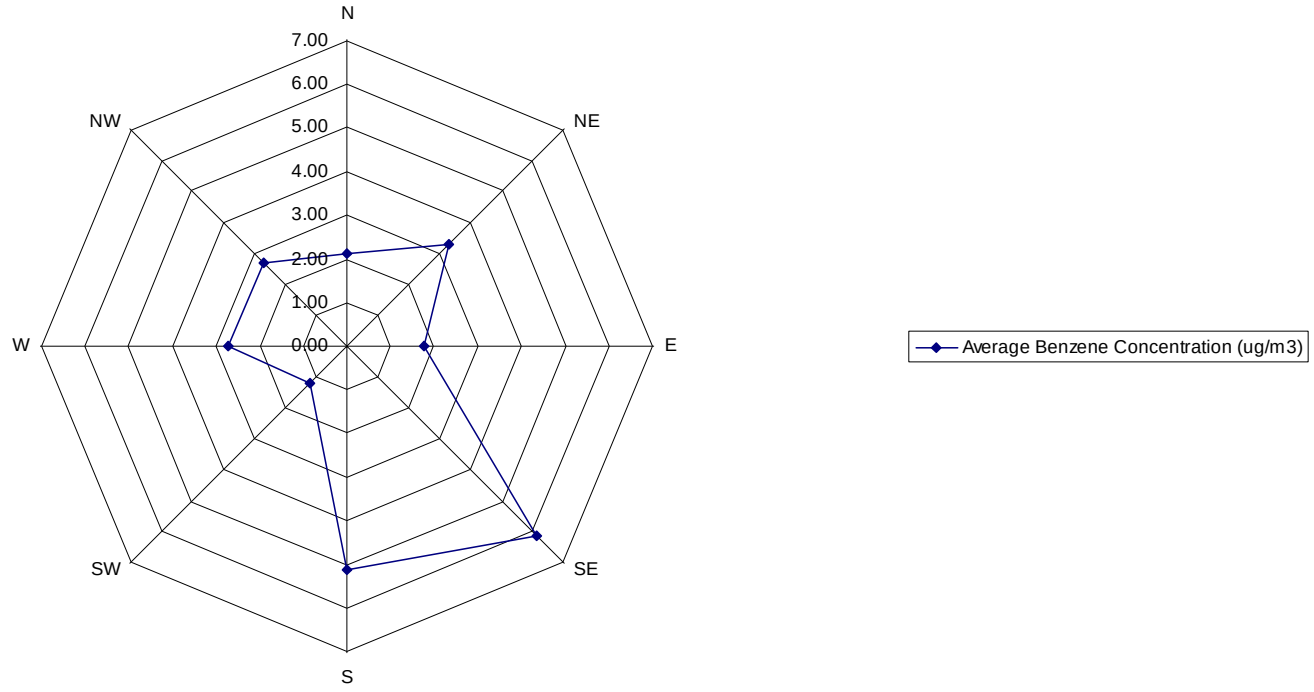
Benzene Pollution Rose: Lewis Elementary School



Risk Assessment

- Two Basic Approaches:

  - Maximum Individual Risk (assumes continuous 70-year exposure at the location of highest predicted ambient concentration)

  - Population-Based (gives the expected total number of cancer cases across a modeled population using census data and risk predictions at census block centroids)

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Benzene Cancer Risk Calculations

Maximum Individual Cancer Risk = (IUR) x (Air Concentration) x (Exposure Duration, Yrs.) / (70 Years)

e.g., for 1 $\mu g/m^3$ and 70-year exposure, max. individual risk = 7.8×10^{-6}

Exposure assessment must account for more realistic exposure durations, human activity patterns, and indoor/outdoor concentration relationships, occupational exposure, i.e.,

"individuals typically do not occupy the same residence for longer than 9 years on average, and less than 0.1% of the population is estimated to reside in one location for greater than 70 years“ (EPA, Risk Assessment Document for Coke Oven MACT Residual Risk, 2003)

e.g., for 1 $\mu g/m^3$ and 9-year exposure, max. individual risk = 1.0×10^{-6}

Population-Based Cancer Risk Assessment

- Multiply the individual excess cancer risk times the number of exposed residents to get the expected cancer incidence rate (number of people per year)
- Considers the spatial distribution of residents living near a plant
- The air quality impact of an industrial facility decreases rather rapidly with increasing distance, such that exposure is typically limited to relatively few people living near the plant
- Many more residents within the urban area are exposed to pollutants emitted by numerous area and mobile sources, which tend to be more widespread

Population-Based Cancer Risk Assessment (cont.)

Cancer Incidence Rate from a Coke Plant: assume 5,000 people exposed to an annual benzene concentration of 8.0 $\mu g/m^3$,

$(7.8 \times 10^{-6})(8.0\ \mu g/m^3)(1/70)(5{,}000\ \text{people}) = 0.004$ people per year

Cancer Incidence Rate Due to Urban Mobile/Area Sources: assume 500,000 people exposed to an annual benzene concentration of 3.3 $\mu g/m^3$,

$(7.8 \times 10^{-6})(3.3\ \mu g/m^3)(1/70)(500{,}000\ \text{people}) = 0.184$ people per year

This example shows that the cancer incidence rate due to urban mobile and area sources is over 40 times greater than that due to a coke plant.

Typical Benzene Exposure Concentrations

Location	Concentration ($\mu g/m^3$)
Remote Areas	<0.5
Rural Areas	0.5 - 1.5
Urban areas	1.5 - 4
Urban "Street Canyons"	8 - 48
Breathing Zone During Automobile Refueling	10 - 3,200
Inside Homes with Smokers	10.5 (median)
Inside Homes Without Smokers	7 (median)
Interior of Cars While Driving	12 - 50

Routes of Benzene Exposure

Routes of Benzene Exposure	Daily Intake (µg/day)
Ambient Outdoor Air	14
Indoor Air	140
Car Refueling and Commuting	49
Food and Drinking Water	1.4
Note: Cigarette smoking may add as much as 1800 µg/day and passive smoking 50 µg/day	

Human Exposure to Benzene

U.S. study indicates the following contributors to benzene exposure:

- 45% from cigarettes
- 18% from automobile and truck exhaust
- 34% from individual activities, such as use of consumer products, common household cleaning supplies, garden equipment (e.g., lawnmowers), outdoor grills, and building supplies
- 3% from industry emissions

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Risk Comparison

Cause of Death or Illness	Certainty of Harm (10^{-6})
Smoking	210,000
Motor Vehicle Accidents	9,430
Passive Smoking	7,000
Medical Xrays	1,400
Drowning	890
Aircraft Accidents	290
Electrocution	150
Coke Plant Fenceline Benzene Exposure	100
Benzene Exposure 0.5 Mile from Coke Plant	75
Lightning	35
Urban Benzene Exposure	25
Benzene Exposure 1.0 Mile from Coke Plant	25
Rural Benzene Exposure	5

Conclusions

- The increased tightening of ambient air quality standards for $PM_{2.5}$ and heightened concerns over health impacts from air toxics place increasing importance on accurate air pollution source allocation
- There are a multitude of analytical tools for $PM_{2.5}$/air toxics source apportionment which, when used in concert, can provide accurate information on source contributions to monitored air pollutant concentration data ("weight-of-evidence" approach)

Conclusions (cont.)

- Chemical speciation data are essential for accurate $PM_{2.5}$ source allocation (e.g., industrial vs. mobile sources)
- Dispersion modeling of coke battery emissions must account for buoyancy enhancement due to radiation and convective heat transfer
- $PM_{2.5}$ and air toxic impacts of coke plants are typically limited to within about one mile of the plant, beyond which ambient concentrations approach those of the general urban environment

Conclusions (cont.)

- Highest annual benzene concentrations recorded in the Tonawanda and Birmingham community air monitoring studies are ~ 8-10 $\mu g/m^3$, which correspond to excess lifetime cancer risks of ~ 6-8 x 10^{-6}
- Elevated $PM_{2.5}$ and air toxic concentrations (benzene) occur largely within several hundred meters of major roadways
- Application of the new EPA MOVES model will result in significantly higher predicted $PM_{2.5}$ concentrations from mobile sources
- Overall, urban benzene concentrations are due primarily to onroad and nonroad mobile sources and area sources (e.g., gas stations)

Conclusions (cont.)

- The ambient benzene/toluene ratio is a useful indicator of coke plant impact
- Human exposure to benzene is almost entirely through inhalation
- Human activities such as smoking, refueling of automobiles, commuting, operation of garden equipment and outdoor grills, use of household products, etc. typically contributes most of this exposure, with industrial emissions contributing very small amounts
- The cancer risks of living near a coke plant (1-100 per million) are relatively small compared to the general population's overall risk of developing cancer (~400,000 per million) and other risks we encounter in everyday life

Conclusions (cont.)

- Health risk assessments based on the maximum exposed individual are highly conservative and often misleading
- Population-based risk assessments that account for the spatial distribution and exposure duration of residents near a facility provide a more realistic estimate of cancer incidence rates and are more likely to show that the health impacts from coke plant emissions are small compared to that of urban-scale area and mobile sources