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URBAN-AIR TOXICS MODELING AND MODEL EVALUATION FOR THREE PILOT CITIES

TECHNICAL MEMORANDUM
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1. INTRODUCTION

The third phase of the analysis of the National Air Toxics Data Archive consisted of (a) the analysis of air toxics monitoring data and (b) the evaluation of air toxics modeling. Both facets of the project build upon previous and ongoing analyses and evaluations. This memorandum documents the methods applied in the air toxics modeling component of the analysis and the results of the model evaluation using pilot-city data.

1.1 BACKGROUND AND OBJECTIVES

Current Government Performance and Results Act (GPRA)[1] commitments "specify a goal of reducing air toxics emissions by 75% from 1993 levels to significantly reduce the risk to Americans of cancer and other serious adverse health effects caused by airborne toxics" (Ryerson et al., 2001). The national air toxics program has been designed with a multi-faceted approach, combining many agencies' activities, to provide the information needed to address and eventually meet the GPRA goal. One of the activities is the National Air Toxics Assessment (NATA), which includes air toxics monitoring made at regional, community, and neighborhood/micro scales and subsequent data analyses. On a national or regional scale, measurements and analyses are made to investigate spatial and temporal trends, establish background concentrations, and perform comparisons among regions. On a neighborhood/micro scale, measurements are made to investigate specific compounds of local concern, investigate specific sources or source types, and generally focus on small areas with potentially high air toxics concentrations. Community-scale measurements focus on providing data to characterize typical community exposure and to assess the associated risk.

The ultimate objective of an analysis of community-scale air toxics monitoring data is to answer a range of policy-relevant questions related to community exposure. The objective of this study's model evaluation task is to prepare limited model-to-monitor comparisons, which complement ongoing modeling work by the U.S. Environmental Protection Agency (EPA).

Air quality models are mathematical tools that simulate atmospheric processes, including transport, diffusion, transformation, and removal. Air quality models have been used for decades to assess the potential impact of emission sources on ambient concentrations of criteria and toxic air pollutants. In the past decade, air quality models have also been used as planning tools for criteria pollutants. However, until recently, air quality models have not been used as planning tools for toxics, due to the lack of measurements with which to evaluate the models. There is a clear need to assess the usefulness of these models in air quality planning and to improve both modeling and evaluation methods. A recent review of air toxics modeling, prepared under contract to the Coordinating Research Council (Seigneur et al., 2002), recommended that model simulation results should be compared with available data to determine their reliability. In fact, one of the objectives of the national monitoring program is to "provide data to support and

[1] The Government Performance and Results Act of 1993 (GPRA) requires that federally funded agencies develop and implement an accountability system based on performance measurement, including setting goals and objectives and measuring progress toward achieving them.

evaluate dispersion and deposition models" (Nizich, 2001). The purpose of this activity is to evaluate the performance of one or more air quality models using data from three pilot cities.

1.2 OVERVIEW OF APPROACH

There are a number of broad policy-relevant questions that could be addressed through modeling analyses, such as

- What are the uncertainties in modeling?
- How should models be used in risk assessments?
- Are the models robust enough for toxics assessments?
- Are the models robust enough to use in air quality planning?

Each of these broad questions can be further divided into numerous specific technical questions. It was not the intent of this study to address all of these questions. Instead we focused on a few technical issues that, in part, answer both how good models are and what the uncertainties are in modeling:

- Can current models predict the range, variability, and gradients of measured toxics?
- How robust was the modeling approach used in this study?
- How does the performance of the current modeling compare to that done for the 1996 NATA?
- How representative were the toxics emission inventories used and what is the impact of inventory quality on predicted concentrations?
- How can background concentrations for toxics be defined for use in near-source modeling?
  - Are there sufficient measurements to establish operational background concentrations?
  - What alternatives to using measurements can be used for establishing background concentrations?
- What are the impacts of complex meteorology, terrain, and emissions patterns on predicted concentrations?
- Should current modeling tools be used in air toxics planning?

In this study, STI explored model performance issues using measurement data from the 10-city pilot study. The modeling and evaluation focused on the cities of Detroit, Michigan; Seattle, Washington; and Cedar Rapids, Iowa. The presence of large water bodies adjacent to two of these cities produces complex meteorological conditions that will significantly challenge the models being evaluated.

Because toxics are assessed using annual concentrations, air quality models for toxics must be applied over entire years to obtain annual concentrations or the annual concentrations derived from a composite of numerous shorter periods. As a result, air quality models for toxics have used simpler meteorological inputs and simpler (if any) representations of chemical

transformations than those used in planning for criteria pollutants (e.g., ozone). These simplifications can lead to errors in both the pollutant concentration and spatial distribution, which reduces a model's utility as a planning tool. Through the model evaluation process, we identified potential modeling issues that can guide the selection of alternative models to apply and evaluate in the future.

1.3 CONTENTS OF THIS TECHNICAL MEMORANDUM

This memorandum includes the methods used in modeling air toxics and evaluating model performance (Section 2), the results of the model evaluation (Section 3), a discussion of the results (Section 4), summary and conclusions (Section 6), and references (Section 6). Two appendices provide additional detailed results in the form of monthly tables of predicted and observed concentrations (Appendix A) and plots that show monthly variations in model performance for each species (Appendix B).

2. METHODOLOGY

2.1 OVERVIEW

The Assessment System for Population Exposure Nationwide (ASPEN) (Rosenbaum et al., 1999) was used to model toxics during the NATA. Evaluations of the ASPEN dispersion module (ASPENA) following the NATA found that, in general, at the exact monitor locations, the model estimates were lower than the monitor averages for most of the pollutant/monitor combinations (U.S. Environmental Protection Agency, 2003). For urban-scale toxics modeling, the Industrial Source Complex Short Term model version 3 (ISCST3) (U.S. Environmental Protection Agency, 1995) is recommended in EPA guidance on urban-scale toxics modeling (U.S. Environmental Protection Agency, 1999a). In this study, ISCST3 was used to model urban air toxics in Detroit, Seattle, and Cedar Rapids, and the model results were evaluated using data from the pilot city study.

2.2 DATA

Geophysical, meteorological, air quality, and emissions data were required for this study. Geophysical, meteorological, and emissions data were required to prepare model inputs while air quality data were required for model evaluation. Sonoma Technology, Inc. (STI) acquired and reviewed all data prior to preparing model inputs.

Terrain elevation at each source and receptor are required for ISCST3. Digitized terrain elevation data were acquired from the U.S. Geological Survey (USGS).

STI acquired standard National Weather Service (NWS) meteorological observations (surface and aloft) for Seattle, Detroit, and Cedar Rapids for use in the air quality simulations.

The Final 1999 National Emissions Inventory Version 3 for Hazardous Air Pollutants was the source of emissions data for this study.

Toxics data for Seattle, Detroit, and Cedar Rapids were taken from the 10-city pilot study data set acquired and validated in the characterization of air toxics component of this study.

2.3 MODEL INPUTS

2.3.1 Geophysical

STI used in-house Geographical Information System (GIS) applications to prepare elevation data inputs for ISCST3.

2.3.2 Meteorology

Because meteorological data were not available in a form suitable for the Meteorological Processor for Regulatory Models (MPRM) (U.S. Environmental Protection Agency, 1996), a custom program based on MPRM was used to create ISCST3 input files from hourly METAR[2] format surface observations and twice-daily upper air observations from the National Oceanic and Atmospheric Administration (NOAA) Forecast Systems Laboratory (FSL).

2.3.3 Emissions

STI used the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system (Houyoux et al., 2000) to process the toxics emissions data and allocate the data spatially, chemically, and temporally for the following emission types:

- Point: allocated to specific locations,
- Non-point: county-level emissions allocated to 1-km grid cells,
- On-road mobile: county-level emissions allocated to 1-km grid cells using surrogates for major road segments such as interstates, U.S. highways, and state highways, and
- Non-road mobile: county-level emissions allocated to 1-km grid cells.

Twelve spatial surrogates were developed using GIS software for distributing non-point sources emissions to the 1-km grid cells. Four of these surrogates were for different road types and were used to allocate on-road mobile source emissions. The remaining eight surrogates and their associated source categories are described in **Table 2-1**. All sources within 50 km of toxics monitoring sites in each city were processed. A SMOKE postprocessor was prepared and applied to reformat the emissions for input to ISCST3.

[2] METAR is the international standard code format for hourly surface weather observations which is analogous to the SA (Surface Airways) coding currently used in the US. The acronym roughly translates from French as Aviation Routine Weather Report.

Table 2-1. Surrogate descriptions and associated source categories.

Surrogate Description	Population Density	Inverse Population Density	Commercial Airports	Recreational Lakes & Bays	Urban Area	Rural Area	County Area	Commercial Marine
Sources Categories	Dry Cleaning Lawn & Garden Equipment Misc. Commercial Solvent Utilization Gas Stations Residential Waste Burning Charcoal Grilling Structure Fires Hospitals Swimming Pools	Boilers - Electrical Generation Boilers - Industrial Boilers - Commercial Internal Combustion Engines (ICEs) - Electrical Generation ICEs - Industrial ICEs - Commercial ICEs - Engine Testing Industrial Processes Solvent Utilization - Ind/Comm MACT Source Categories Off-Highway Vehicles - Ind/Comm Petroleum Storage and Transport Repair Shops	Airport Ground Support Equipment Military Aircraft Commercial Aircraft General Aviation Air Taxi	Pleasure Craft	Building Construction Site Remediation Architectural Coatings Auto Refinishing Traffic Markings Publicly Owned Treatment Works (POTWs)	Landfills Food and Agricultural Production Recreational Equipment Agricultural Equipment Logging Equipment Mining Equipment Open Burning Biogenic Sources Geogenic Sources	Paving/Surfacing Equipment Railroad Equipment Misc. Construction Misc. Solvent Utilization Petroleum Working Losses Petroleum Transport (non-Marine) Organic Chemical Transport (non-Marine) Bulk Materials Transport (non-Marine)	Commercial Marine Vessels Petroleum Transport (Marine) Organic Chemical Transport (Marine) Bulk Materials Transport (Marine)

2.4 AIR QUALITY MODELING

STI performed air quality modeling for 13 of 18 core hazardous air pollutants (HAPs) for the cities of Seattle, Detroit, and Cedar Rapids. The modeling was performed using routine single-station meteorology as input. The ISCST3 model (U.S. Environmental Protection Agency, 1995) was used as recommended in EPA guidance on urban scale toxics modeling (U.S. Environmental Protection Agency, 1999a).

2.4.1 Modeling Domains

ISCST3 was applied with receptors defined at toxics monitoring sites and for a radial grid of 25 receptors extending 4.5 km around the site. The emissions domains were designed to encompass all areas within 50 km of the pilot study monitoring sites and are shown below for Seattle (**Figure 2-1**), Detroit (**Figure 2-2**), and Cedar Rapids (**Figure 2-3**).

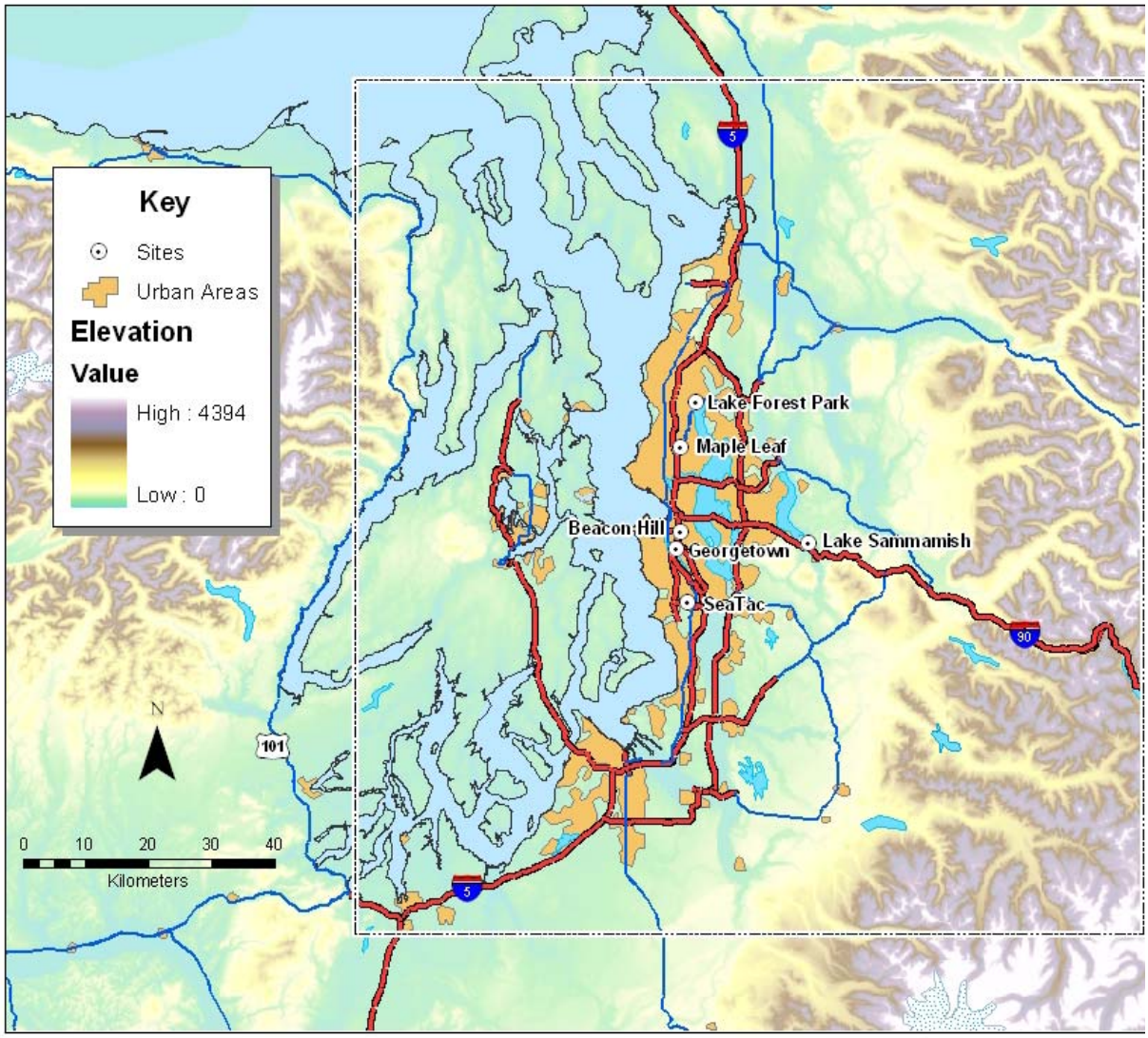

Figure 2-1. Modeling domain for Seattle.

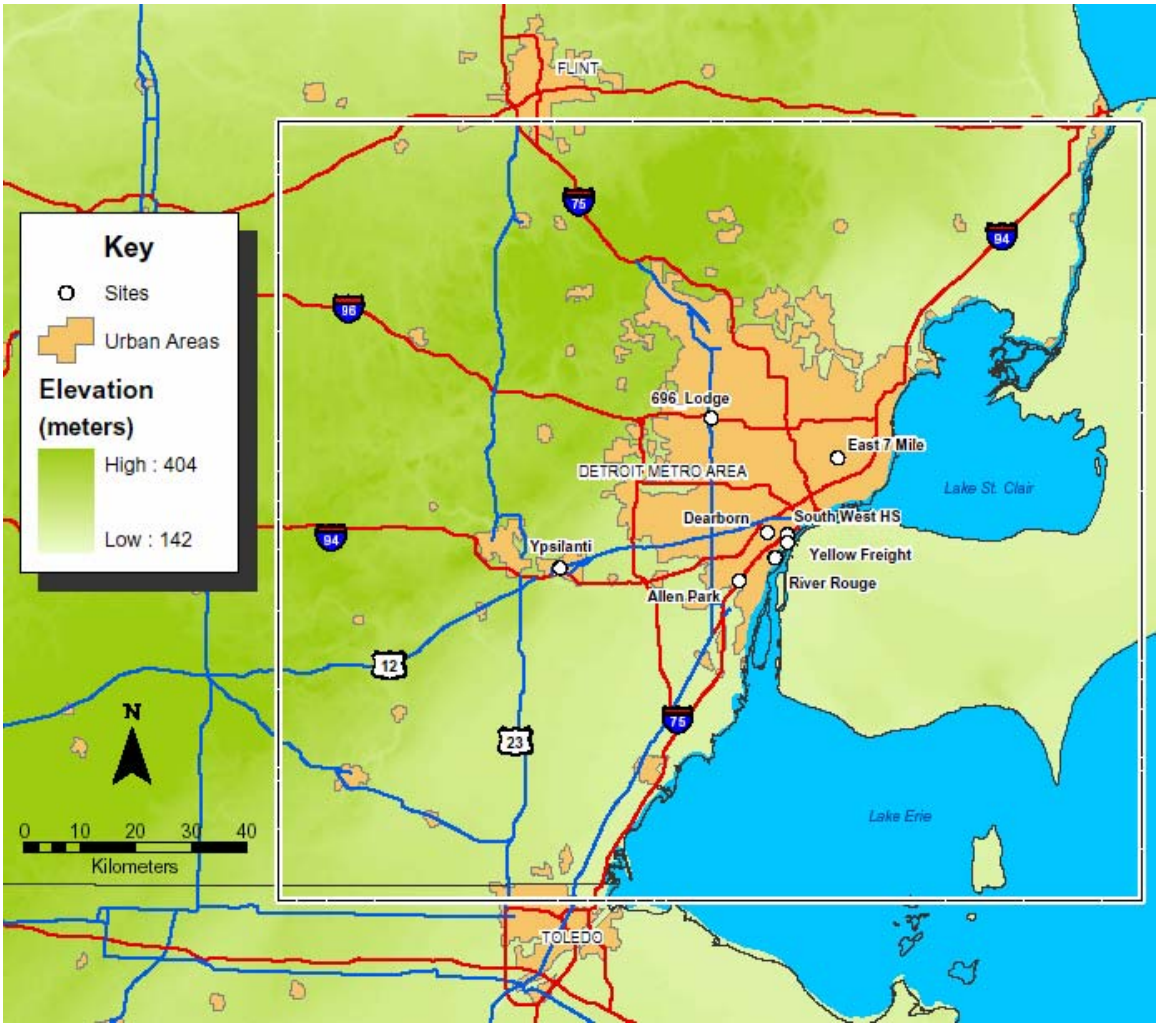

Figure 2-2. Modeling domain for Detroit.

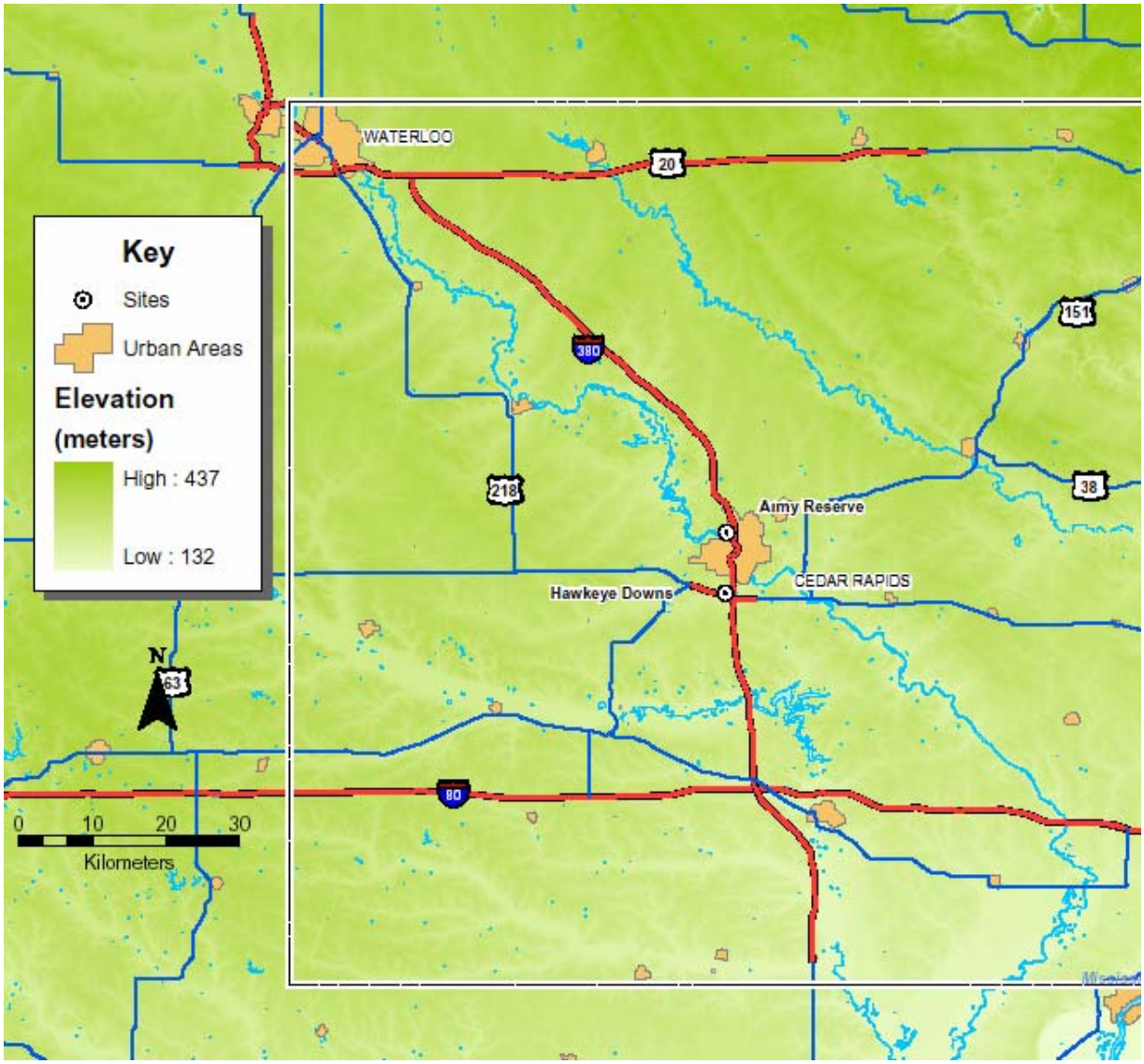

Figure 2-3. Modeling domain for Cedar Rapids.

2.4.2 Selection of Time Periods for Modeling

The time period used to evaluate the model results for each city was chosen by the number of measurements taken in each month. A one-year time period was chosen for each city during the time where the most measurements were available in concurrent months. The time periods selected are shown in **Table 2-2**.

Table 2-2. Time periods of observations used in model analysis.

City	Time Period Start	Time Period End
Cedar Rapids	1/1/2001	12/31/2001
Detroit	5/1/2001	4/30/2002
Seattle	3/1/2001	2/28/2002

2.4.3 Selection of Species for Modeling

Only species with a significant number of observations available were modeled. To assess the availability of data, the number of observations of each of the 18 core HAPs were totaled and sorted by species, and location, and categorized as 'reported', 'non-detect', or 'invalid' based on the following criteria:

- 'Reported' concentrations are data for which an actual value was reported, regardless of whether it was above or below the minimum detection limit (MDL).
- 'Non-detects' are data for which no value was reported, but concentrations are known to be below the MDL.
- 'Invalids' are data for which no value was reported due to various issues/problems with the sample or analysis.

Invalid data were not used in this study. For each species and city, the percent of non-detect observations to total observations was calculated, and used to decide which species to model. These data are shown in **Table 2-3** where the percent 'non-detects' greater than 50% are shown in bold and the dash (-) symbol indicates no observations at the site. The species selected for modeling are shown in the last row of Table 2-3.

The species 1,2-dichloropropane, chloroform, trichloroethylene, and vinyl chloride were all not modeled because of a lack of observational data above the MDL . Carbon tetrachloride was not modeled because there are effectively no emissions in the inventory and concentrations are at background levels. We chose to model 1,3-butadiene even though its concentrations were frequently below the MDL for most observations because it is a very reactive species, and low concentrations are to be expected. We chose to model tetrachloroethylene based on data availability for Seattle (and other pilot cities) even though concentrations in Cedar Rapids and Detroit were frequently below the MDL. **Table 2-4** shows the number of months with valid observations at each site for the species modeled.

Table 2-3. Summary of available data for the 18 core HAPs.

		Carbonyl		Metal							Volatile Organic Compounds (VOCs)								
	City	Acetaldehyde	Formaldehyde	Arsenic TSP	Beryllium TSP	Cadmium TSP	Chromium TSP	Lead TSP	Manganese TSP	Nickel TSP	1,2-Dichloropropane	1,3-Butadiene	Benzene	Carbon Tetrachloride	Chloroform	Methylene Chloride	Tetrachloroethylene	Trichloroethyl;ene	Vinyl Chloride
Number of Reported Concentrations	Cedar Rapids	163	165	0	0	0	0	0	0	0	0	27	172	146	23	143	19	1	0
	Detroit	728	722	480	479	479	480	480	480	480	0	345	692	659	99	615	278	43	0
	Seattle	351	345	290	173	289	287	290	290	289	0	388	389	349	351	352	351	350	0
Number of Non-detects	Cedar Rapids	0	0	0	0	0	0	0	0	0	172	145	0	0	149	29	153	171	172
	Detroit	0	0	0	1	1	0	0	0	0	700	355	8	0	601	85	422	657	700
	Seattle	0	0	0	120	0	1	0	0	0	364	1	0	0	0	0	0	0	364
Percent Non-detect	Cedar Rapids	0%	0%	-	-	-	-	-	-	-	**100%**	**84%**	0%	0%	**87%**	17%	**89%**	**99%**	**100%**
	Detroit	0%	0%	0%	0%	0%	0%	0%	0%	0%	**100%**	**51%**	1%	0%	**86%**	12%	**60%**	**94%**	**100%**
	Seattle	0%	0%	0%	41%	0%	0%	0%	0%	0%	**100%**	0%	0%	0%	0%	0%	0%	0%	**100%**
Modeled	All	✓	✓	✓	✓	✓	✓	✓	✓	✓	No	✓	✓	No	No	✓	✓	No	No

TSP = total suspended particulate

Table 2-4. Number of months with valid observations at each site. The numbers in *gray italics* indicate values computed with 50% or more observational data flagged as 'non-detect'.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	12	12								*12*	12	12	*12*
	Hawkeye Downs	12	12								*12*	12	12	*12*
Detroit	696_Lodge	12	12	12	12	12	12	12	12	12	*12*	12	12	*12*
	Allen Park	12	12	12	12	12	12	12	12	12	*12*	12	12	*12*
	Dearborn	12	12	12	12	12	12	12	12	12	*12*	12	12	*12*
	East 7 Mile	12	12	12	12	12	12	12	12	12				
	River Rouge	12	12	12	12	12	12	12	12	12	*12*	12	12	*12*
	South West HS	12	12	12	12	12	12	12	12	12	*12*	12	12	*12*
	Yellow Freight	12	12	12	12	12	12	12	12	12	*12*	12	12	*12*
	Ypsilanti	12	12	8	8	8	8	8	8	8	*12*	12	12	*12*
Seattle	Beacon Hill	12	12								12	12	12	12
	Georgetown	12	12								12	12	12	12
	Lake Forest Park	12	12	12	12	12	12	12	12	12	12	12	12	12
	Lake Sammamish	12	12	12	12	12	12	12	12	12	12	12	12	12
	Maple Leaf Reservoir	12	12	12	12	12	12	12	12	12	12	12	12	12
	Sea Tac	12	12	12	12	12	12	12	12	12	12	12	12	12

TSP = total suspended particulate

2.4.4 Chemistry

The ISCST3 model provides concentration estimates due to primary emissions and has a limited capability to consider atmospheric transformations by exponential decay. In addition, some pollutants are formed in the atmosphere due to reactions among other pollutants. Thus, in addition to estimating concentrations due to primary emissions, an estimate of concentrations based on secondary production must be added to the ISCST3 output in order to avoid large underpredictions.

EPA's Ozone Isopleth Plotting for Research (OZIPR) model (Gery and Crouse, 1992) may be used to estimate the secondary transformation of acetaldehyde, formaldehyde, and acrolein. The U.S. Environmental Protection Agency (1999b) describes an approach where secondary toxics production is estimated with the stand-alone OZIPR model that incorporates only nondispersive processes, such as photochemistry. In that approach, the results from this model are then coupled with output from the ISCST3 model, which accounts for dispersion but not for chemical transformation. The EPA approach was evaluated in this study for acetaldehyde and formaldehyde.

2.4.5 Background Concentrations

Background air quality includes pollutant concentrations due to natural sources, nearby sources other than those under consideration, and unidentified sources. For typical exposure assessments, background concentrations should be added to the modeled concentrations to provide total ambient air concentrations for estimating exposure. Air quality data from the toxics monitoring and related networks (i.e., PAMS, IMPROVE, CASTNet, NOAA, etc.) were used to establish background concentrations. The background concentrations used are summarized in **Table 2-5**.

Table 2-5. Background concentrations used in the model evaluation.

Species	Background Concentration
1,3-Butadiene	0.01 µg/m^3
Acetaldehyde	0.16 µg/m^3
Benzene	0.142 µg/m^3
Formaldehyde	0.2 µg/m^3
Methylene Chloride	0.086 µg/m^3
Tetrachloroethylene	0.022 µg/m^3
Arsenic	0.00013 µg/m^3
Beryllium	0.0 µg/m^3
Cadmium	0.0 µg/m^3
Chromium	0.00004 µg/m^3
Lead	0.00049 µg/m^3
Manganese	0.00058 µg/m^3
Nickel	0.000065 µg/m^3

2.5 MODEL PERFORMANCE EVALUATION

The model results were compared with the measured data for 13 HAPs using both graphical and statistical methods. The evaluation used the methods from the NATA evaluations, which include scatter plots, ratio box plots, number of sites, median of ratios, percent of sites within a factor of two and within 30%, percent of sites underestimated, and other statistics.

Monitor values below the MDL were flagged and one-half the MDL was used for computation of monitor averages. For some pollutant/monitor combinations, many of the monitor readings were below the MDL. For these low-concentration sites, we did not have confidence in the monitored annual averages based on an analysis performed by Battelle. Therefore, any metrics calculated with 50% or less of data above the MDL were flagged and should be used with caution.

2.5.1 Statistical Evaluation

Number of Sites

The number of sites is the number of monitors for each pollutant.

Mean Concentrations

Monthly and annual mean modeled and measured concentrations of each pollutant will be compared.

Bias Statistics

Bias statistics are useful in identifying and quantifying biases in model predictions. Mean absolute bias (ABIAS) provides measure of bias in concentration units. ABIAS is calculated as in Equation 3-1.

$$ABIAS_{threshold} = \frac{1}{N} \sum_{i=1}^{N} Pred_{x,t}^{i} - Obs_{x,t}^{i} \qquad \textbf{(3-1)}$$

where N includes all of the model predicted (Pred) and observed (Obs) concentration pairs with observed concentrations above a threshold concentration (e.g., the MDL) for each species, from all stations in a region during a given year. Note the bias is defined as a positive quantity when the model estimate exceeds the observation.

Mean normalized bias (NBIAS) provides a similar metric but normalized to the observed concentrations and given in percent as shown in Equation 3-2.

$$NBIAS_{threshold} = \frac{100}{N} \sum_{i=1}^{N} \frac{(Pred_{x,t}^{i} - Obs_{x,t}^{i})}{Obs_{x,t}^{i}} \qquad \textbf{(3-2)}$$

Error Statistics

Error statistics provide estimates of model uncertainty and information complementary to that obtained from bias statistics since unbiased models can still exhibit large errors in their prediction. Mean absolute error (AERROR in concentration units) and mean normalized error

(NERROR in percent) calculations are similar to their corresponding bias statistics but employ the absolute value of the model prediction and measured concentration differences. The calculations of AERROR and NERROR are shown in Equations 3-3 and 3-4, respectively.

$$AERROR_{threshold} = \frac{1}{N}\sum_{i=1}^{N} | Pred_{x,t}^{i} - OBS_{x,t}^{i} | \quad \textbf{(3-3)}$$

$$NERROR_{threshold} = \frac{100}{N}\sum_{i=1}^{N} \frac{| Pred_{x,t}^{i} - OBS_{x,t}^{i}|}{Obs_{x,t}^{i}} \quad \textbf{(3-4)}$$

Median of Ratios

The median of ratios is based on the model/monitor ratios for a given pollutant. A median close to one (1) suggests that the model overestimates the monitors about as often as it underestimates the monitors. This statistic is also shown on the ratio box plots.

Percent of Sites Estimated "within a factor of *x*".

This statistic is based on the model/monitor ratios for a given pollutant. We calculated the percent of sites for a given pollutant which agree within a factor of two, which is the percent of sites for which the model estimate is somewhere between half and double the monitor average. The percent of sites estimated within 30% (percent of sites for which the model to monitor ratio is between 0.7 and 1.3) was also calculated.

MAXTOMON

This technique compares the MAXimum model estimate within *r* kilometers of the monitor TO the MONitor average. All model estimates are considered (both estimates at monitor sites as well as the estimates at cell centers) in finding the maximum values. This is an example of a point-to-range technique. This technique is used to test whether biases in the model predictions at monitoring sites are due to location uncertainties or due to systematic model biases.

BESTTOMON

The MAXTOMON statistic has been used in past toxics modeling studies because of the tendency to underpredict concentrations. Because there were overpredictions in this study, we modified the MAXTOMON technique to create a BESTTOMON statistic. This technique compares the BEST model estimate within *r* kilometers of the monitor TO the MONitor average. All model estimates are considered (both estimates at monitor sites as well as the estimates at cell centers) in finding the maximum values. This is an example of a point-to-range technique. This technique is used to test whether biases in the model predictions at monitoring sites are due to location uncertainties or due to systematic model biases.

2.5.2 Graphical Evaluation

Scatter Plots

Scatter plots are a graphical technique to show the relationship between two variables. Model estimates of annual averages will be plotted against monitor averages. Each ordered pair on the graph is plotted for each monitoring site for that pollutant. Because fewer monitors were used in this analysis than in a national analysis, monthly averages were also plotted.

Ratio Box Plots

Ratio box plots show the same data as the scatter plots but in a different fashion. Each box shows the distribution of model-to-monitor ratios. The plots show the median, 25th, and 75th percentiles of the ratios.

A logarithmic scale was used for the vertical axis because using a regular arithmetic scale on the vertical axis would put a ratio of 2.0 twice as far from 1.0 as a ratio of 0.5. However, modelers typically speak of estimates as "within a factor of *x*". An underestimate by a factor of *x* should look just as erroneous as an overestimate by a factor of *x*. A logarithmic scale makes the overestimation and underestimation the same distance from the horizontal line where the ratio is 1.0.

The ratio box plots are displayed side by side, one for each pollutant. This display format allows us to see easily which toxics are being overestimated and underestimated, and which are being estimated consistently.

3. RESULTS

The section presents the results of the model evaluation analyses performed. The results are further summarized and discussed in Section 4.

3.1 MEAN OBSERVED AND PREDICTED CONCENTRATIONS

Annual average model-predicted concentrations of 13 HAPs are provided in **Table 3-1**. These predicted concentrations include the background concentrations described in Section 2.4.5 but do not include secondary production for chemically reactive species. The secondary component can be substantial for acetaldehyde and formaldehyde (i.e., 90% of the total) and should be kept in mind when comparing predicted and observed concentrations. Secondary production of HAPs is discussed further in Section 3.8.

Annual average observed concentrations for 13 modeled HAPs are shown in **Table** 3-2 where numbers in *gray italics* indicate values computed with 50% or more observational data flagged as 'non-detect'. The measurements with high non-detect rates include 1,3-butadiene and tetrachloroethylene in Cedar Rapids and Detroit.

3.2 BIAS AND ERROR STATISTICS

Bias statistics for annual average model predictions are proved in **Table 3-3** (absolute bias) and **Table 3-4** (normalized bias). Error statistics for annual average model predictions are proved in **Table 3-5** (absolute error) and **Table 3-6** (normalized error).

Table 3-1. Annual average predicted concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	0.1974	0.2705								0.0318	0.3376	0.1482	0.0525
	Hawkeye Downs	0.1930	0.2589								0.0277	0.3063	0.1247	0.0408
	Average	**0.1952**	**0.2647**								**0.0298**	**0.3220**	**0.1365**	**0.0467**
Detroit	696_Lodge	0.4077	0.8027	0.00016	0.0000053	0.00022	0.00011	0.00257	0.00114	0.00076	0.1933	1.9760	0.3001	0.3619
	Allen Park	0.3374	0.5900	0.00015	0.0000031	0.00084	0.00010	0.00242	0.00140	0.00082	0.1337	1.5431	0.4360	0.4224
	Dearborn	0.3138	0.5337	0.00016	0.0000039	0.00019	0.00022	0.00394	0.00716	0.00153	0.1118	1.3146	0.4010	0.4757
	East 7 Mile	0.2840	0.4741	0.00026	0.0000054	0.00087	0.00042	0.00329	0.00188	0.00103				
	River Rouge	0.2629	0.4014	0.00015	0.0000030	0.00028	0.00014	0.00861	0.00836	0.00152	0.0700	0.9342	0.3540	0.3729
	South West HS	0.3271	0.5733	0.00015	0.0000031	0.00042	0.00020	0.00599	0.00794	0.00518	0.1235	1.4090	0.3686	0.4020
	Yellow Freight	0.2811	0.4519	0.00016	0.0000036	0.00038	0.00023	0.01106	0.02659	0.00281	0.0816	1.0920	0.4236	0.4400
	Ypsilanti	0.2493	0.3998	0.00016	0.0000027	0.00064	0.00012	0.00181	0.00074	0.00035	0.0721	0.8122	0.2513	0.1895
	Average	**0.3079**	**0.5284**	**0.00017**	**0.0000038**	**0.00047**	**0.00020**	**0.00510**	**0.00717**	**0.00181**	**0.1123**	**1.2973**	**0.3621**	**0.3806**
Seattle	Beacon Hill	0.4989	0.9645								0.1739	2.4328	0.3762	0.1531
	Georgetown	0.6711	1.5013								0.2397	2.7864	0.7505	0.1970
	Lake Forest Park	0.5115	1.0425	0.00018	0.0000002	0.00009	0.00066	0.00180	0.00152	0.00019	0.1821	2.5265	0.4131	0.1857
	Lake Sammamish	0.3540	0.6221	0.00015	0.0000001	0.00004	0.00029	0.00107	0.00086	0.00011	0.1041	1.4904	0.2136	0.0910
	Maple Leaf Reservoir	0.4283	0.7170	0.00014	0.0000001	0.00004	0.00065	0.00249	0.00159	0.00047	0.1448	2.0578	0.2869	0.0970
	Sea Tac	0.7485	1.7012	0.00018	0.0000002	0.00011	0.00075	0.02511	0.00209	0.00022	0.2653	2.8945	0.4250	0.2090
	Average	**0.5354**	**1.0915**	**0.00016**	**0.0000001**	**0.00007**	**0.00059**	**0.00762**	**0.00151**	**0.00025**	**0.1850**	**2.3647**	**0.4109**	**0.1555**
All	**Average**	**0.3791**	**0.7066**	**0.00017**	**0.0000026**	**0.00034**	**0.00033**	**0.00596**	**0.00523**	**0.00128**	**0.1304**	**1.5942**	**0.3515**	**0.2460**

Table 3-2. Annual average observed concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	2.59	2.35								*0.08816*	0.93	0.88	*0.21*
	Hawkeye Downs	3.38	2.36								*0.11818*	1.17	0.66	*0.22*
	Average	**2.99**	**2.35**								***0.10317***	**1.05**	**0.77**	*0.21*
Detroit	696_Lodge	1.61	2.45	0.00123	0.00008	0.00019	0.00347	0.00661	0.01534	0.00342	*0.17950*	1.97	63.93	*0.29*
	Allen Park	1.63	2.23	0.00201	0.00008	0.00042	0.00343	0.02785	0.03014	0.00213	*0.11939*	1.51	1001.53	*0.43*
	Dearborn	2.04	3.09	0.00258	0.00012	0.00064	0.00599	0.02471	0.20164	0.00299	*0.10911*	1.88	12.04	*0.45*
	East 7 Mile	1.77	2.81	0.00174	0.00007	0.00036	0.00281	0.01166	0.02700	0.00213				
	River Rouge	2.13	5.80	0.00201	0.00008	0.00066	0.00506	0.01999	0.07677	0.00233	*0.12029*	2.18	11.77	*0.67*
	South West HS	2.04	3.72	0.00213	0.00015	0.00095	0.00602	0.02169	0.09231	0.00346	*0.04423*	2.63	3.59	*0.34*
	Yellow Freight	1.74	3.10	0.00355	0.00035	0.00117	0.00765	0.02909	0.26656	0.00404	*0.18350*	23.29	2.54	*0.28*
	Ypsilanti	1.00	2.08	0.00075	0.00005	0.00017	0.00228	0.00524	0.01015	0.00085	*0.04423*	1.14	0.51	*0.44*
	Average	**1.75**	**3.16**	**0.00206**	**0.00012**	**0.00059**	**0.00469**	**0.01893**	**0.09350**	**0.00275**	***0.11432***	**4.94**	**156.56**	*0.41*
Seattle	Beacon Hill	1.33	1.73								0.07615	1.19	1.49	0.14
	Georgetown	1.19	1.43								0.09763	1.44	1.85	0.34
	Lake Forest Park	1.18	1.07	0.00162	0.00000	0.00016	0.00094	0.00504	0.00499	0.00109	0.11991	1.56	1.75	0.24
	Lake Sammamish	1.28	1.03	0.00085	0.00000	0.00012	0.00086	0.00322	0.00691	0.00092	0.08686	1.13	1.72	0.15
	Maple Leaf Reservoir	1.14	1.20	0.00083	0.00000	0.00011	0.00087	0.00427	0.00555	0.00130	0.07580	1.11	1.96	0.21
	Sea Tac	1.36	1.34	0.00097	0.00000	0.00013	0.00171	0.00479	0.00785	0.00183	0.09787	1.02	1.68	0.14
	Average	**1.25**	**1.30**	**0.00107**	**0.00000**	**0.00013**	**0.00109**	**0.00433**	**0.00633**	**0.00129**	**0.09237**	**1.24**	**1.74**	0.20
All	**Average**	**1.71**	**2.36**	**0.00172**	**0.00008**	**0.00043**	**0.00346**	**0.01392**	**0.06360**	**0.00225**	**0.10405**	**2.94**	**73.86**	0.30

Table 3-3. Absolute bias of annual average predictions in µg/m^3.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	-2.3912	-2.08								*-0.05640*	-0.59687	-0.73254	*-0.15492*
	Hawkeye Downs	-3.1908	-2.10								*-0.09044*	-0.86728	-0.53427	*-0.17566*
	Average	**-2.7910**	**-2.09**								***-0.07342***	**-0.73208**	**-0.63341**	*-0.16529*
Detroit	696_Lodge	-1.2040	-1.65	-0.00107	-0.00007	0.00003	-0.00336	-0.00404	-0.01419	-0.00266	*0.01380*	0.00240	-63.62529	*0.06783*
	Allen Park	-1.2960	-1.64	-0.00186	-0.00008	0.00042	-0.00333	-0.02543	-0.02874	-0.00131	*0.01433*	0.03322	-1001.09194	*-0.01212*
	Dearborn	-1.7238	-2.56	-0.00242	-0.00012	-0.00044	-0.00577	-0.02077	-0.19448	-0.00146	*0.00270*	-0.56478	-11.63485	*0.02622*
	East 7 Mile	-1.4869	-2.34	-0.00148	-0.00007	0.00051	-0.00239	-0.00836	-0.02512	-0.00110				
	River Rouge	-1.8671	-5.40	-0.00186	-0.00007	-0.00039	-0.00492	-0.01138	-0.06841	-0.00080	*-0.05032*	-1.24986	-11.41530	*-0.30038*
	South West HS	-1.7166	-3.15	-0.00198	-0.00015	-0.00052	-0.00582	-0.01570	-0.08437	0.00172	*0.07931*	-1.22418	-3.21813	*0.06092*
	Yellow Freight	-1.4568	-2.65	-0.00340	-0.00034	-0.00079	-0.00742	-0.01803	-0.23997	-0.00122	*-0.10190*	-22.19790	-2.11461	*0.16379*
	Ypsilanti	-0.7519	-1.68	-0.00059	-0.00005	0.00048	-0.00216	-0.00343	-0.00941	-0.00051	*0.02783*	-0.32998	-0.26062	*-0.24556*
	Average	**-1.4379**	**-2.63**	**-0.00189**	**-0.00012**	**-0.00011**	**-0.00449**	**-0.01383**	**-0.08633**	**-0.00094**	***-0.00203***	**-3.64730**	**-156.19439**	*-0.03419*
Seattle	Beacon Hill	-0.8337	-0.77								0.09780	1.24742	-1.11156	0.00895
	Georgetown	-0.5210	0.08								0.14208	1.34932	-1.10068	-0.14162
	Lake Forest Park	-0.6642	-0.03	-0.00145	0.00000	-0.00007	-0.00028	-0.00324	-0.00347	-0.00090	0.06223	0.96261	-1.34003	-0.04977
	Lake Sammamish	-0.9295	-0.41	-0.00070	0.00000	-0.00008	-0.00056	-0.00215	-0.00605	-0.00081	0.01726	0.36459	-1.51101	-0.06257
	Maple Leaf Reservoir	-0.7106	-0.48	-0.00069	0.00000	-0.00006	-0.00022	-0.00178	-0.00396	-0.00083	0.06896	0.94877	-1.67630	-0.10832
	Sea Tac	-0.6078	0.36	-0.00079	0.00000	-0.00003	-0.00095	0.02031	-0.00577	-0.00161	0.16741	1.87348	-1.25175	0.06724
	Average	**-0.7111**	**-0.21**	**-0.00090**	**0.00000**	**-0.00006**	**-0.00050**	**0.00329**	**-0.00481**	**-0.00104**	**0.09262**	**1.12436**	**-1.33189**	-0.04768
All	**Average**	**-1.3345**	**-1.66**	**-0.00155**	**-0.00008**	**-0.00009**	**-0.00313**	**-0.00796**	**-0.05837**	**-0.00097**	**0.02631**	**-1.34994**	**-73.50792**	-0.05707

Table 3-4. Normalized bias of annual average predictions in µg/m^3.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	-91%	-85%								-67%	-63%	-54%	-76%
	Hawkeye Downs	-93%	-87%								-81%	-72%	-70%	-84%
	Average	**-92%**	**-86%**								**-74%**	**-68%**	**-62%**	-80%
Detroit	696_Lodge	-73%	-63%	-76%	-90%	61%	-96%	-48%	-88%	-52%	8%	3%	-56%	-13%
	Allen Park	-78%	-70%	-90%	-94%	108%	-97%	-79%	-95%	-60%	3%	6%	-99%	-28%
	Dearborn	-82%	-82%	-93%	-96%	-66%	-96%	-83%	-95%	-46%	-20%	-30%	-88%	-23%
	East 7 Mile	-83%	-82%	-83%	-91%	178%	-84%	-71%	-93%	-47%				
	River Rouge	-86%	-91%	-92%	-95%	-44%	-97%	-51%	-88%	-26%	-55%	-56%	-63%	-1%
	South West HS	-81%	-80%	-92%	-97%	-46%	-96%	-72%	-92%	58%		-27%	-83%	-39%
	Yellow Freight	-81%	-83%	-95%	-99%	-65%	-97%	-61%	-89%	-28%	-60%	-89%	-63%	61%
	Ypsilanti	-73%	-76%	-78%	-95%	302%	-95%	-64%	-92%	-57%		-26%	-74%	-75%
	Average	**-80%**	**-78%**	**-88%**	**-94%**	**42%**	**-95%**	**-66%**	**-91%**	**-31%**	**-25%**	**-31%**	**-75%**	-8%
Seattle	Beacon Hill	-55%	-34%								183%	122%	-72%	49%
	Georgetown	-40%	12%								170%	105%	-59%	-21%
	Lake Forest Park	-54%	16%	-86%	-92%	-23%	-22%	-60%	-68%	-80%	101%	70%	-73%	38%
	Lake Sammamish	-70%	-15%	-78%	-98%	-63%	-61%	-65%	-86%	-85%	84%	42%	-88%	-19%
	Maple Leaf Reservoir	-60%	-26%	-80%	-95%	-49%	-17%	-40%	-70%	-61%	135%	94%	-85%	-23%
	Sea Tac	-41%	45%	-79%	-96%	-7%	-40%	473%	-65%	-84%	280%	197%	-73%	106%
	Average	**-53%**	**0%**	**-81%**	**-95%**	**-35%**	**-35%**	**77%**	**-72%**	**-78%**	**159%**	**105%**	**-75%**	21%
All	**Average**	**-71%**	**-50%**	**-86%**	**-95%**	**16%**	**-74%**	**-17%**	**-85%**	**-47%**	**63%**	**18%**	**-73%**	-1%

Table 3-5. Absolute error of annual average predictions in µg/m^3.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	2.39117	2.07537								*0.05640*	0.59687	0.73915	*0.15492*
	Hawkeye Downs	3.19079	2.09747								*0.09044*	0.86728	0.53427	*0.17566*
	Average	**2.79098**	**2.08642**								*0.07342*	**0.73208**	**0.63671**	*0.16529*
Detroit	696_Lodge	1.20405	1.64907	0.00107	0.00007	0.00012	0.00336	0.00423	0.01419	0.00268	*0.03345*	0.29630	63.66805	*0.07847*
	Allen Park	1.29598	1.64271	0.00186	0.00008	0.00042	0.00333	0.02543	0.02874	0.00131	*0.02983*	0.29862	1001.09194	*0.18440*
	Dearborn	1.72378	2.55634	0.00242	0.00012	0.00044	0.00577	0.02077	0.19448	0.00146	*0.02055*	0.56478	11.63485	*0.13367*
	East 7 Mile	1.48686	2.33877	0.00148	0.00007	0.00051	0.00239	0.00836	0.02512	0.00113				
	River Rouge	1.86706	5.39570	0.00186	0.00007	0.00039	0.00492	0.01138	0.06841	0.00097	*0.05380*	1.24986	11.41530	*0.49151*
	South West HS	1.71657	3.14870	0.00198	0.00015	0.00052	0.00582	0.01570	0.08437	0.00173	*0.07931*	1.42260	3.21813	*0.19559*
	Yellow Freight	1.45684	2.64978	0.00340	0.00034	0.00079	0.00742	0.01803	0.23997	0.00132	*0.10190*	22.19790	2.11703	*0.19015*
	Ypsilanti	0.75187	1.67820	0.00059	0.00005	0.00048	0.00216	0.00343	0.00941	0.00051	*0.02783*	0.39366	0.26062	*0.24556*
	Average	**1.43788**	**2.63241**	**0.00189**	**0.00012**	**0.00046**	**0.00449**	**0.01386**	**0.08633**	**0.00143**	*0.04952*	**3.77482**	**156.20085**	*0.21705*
Seattle	Beacon Hill	0.83365	0.87397								0.09780	1.24742	1.11156	0.08028
	Georgetown	0.52105	0.25502								0.14208	1.34932	1.10068	0.17513
	Lake Forest Park	0.66417	0.41940	0.00145	0.00000	0.00008	0.00037	0.00324	0.00347	0.00090	0.08535	0.96261	1.34003	0.12447
	Lake Sammamish	0.92949	0.53336	0.00070	0.00000	0.00008	0.00056	0.00215	0.00605	0.00081	0.04259	0.39681	1.51101	0.07106
	Maple Leaf Reservoir	0.71060	0.56256	0.00069	0.00000	0.00006	0.00033	0.00179	0.00396	0.00083	0.07276	0.94877	1.67630	0.12840
	Sea Tac	0.60785	0.52491	0.00079	0.00000	0.00004	0.00106	0.02031	0.00579	0.00161	0.16741	1.87348	1.25175	0.08555
	Average	**0.71113**	**0.52820**	**0.00090**	**0.00000**	**0.00007**	**0.00058**	**0.00687**	**0.00482**	**0.00104**	**0.10133**	**1.12973**	**1.33189**	0.11082
All	**Average**	**1.33449**	**1.77508**	**0.00155**	**0.00008**	**0.00032**	**0.00315**	**0.01146**	**0.05837**	**0.00129**	**0.07343**	**2.31109**	**73.51138**	0.16766

Table 3-6. Normalized error of annual average predictions.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	91%	85%								67%	63%	57%	76%
	Hawkeye Downs	93%	87%								81%	72%	70%	84%
	Average	**92%**	**86%**								**74%**	**68%**	**63%**	**80%**
Detroit	696_Lodge	73%	63%	77%	90%	98%	96%	62%	88%	57%	26%	16%	81%	38%
	Allen Park	78%	70%	90%	94%	108%	97%	79%	95%	60%	25%	20%	99%	38%
	Dearborn	82%	82%	93%	96%	66%	96%	83%	95%	46%	29%	30%	88%	29%
	East 7 Mile	83%	82%	83%	91%	178%	84%	71%	93%	49%				
	River Rouge	86%	91%	92%	95%	46%	97%	51%	88%	37%	55%	56%	63%	76%
	South West HS	81%	80%	92%	97%	46%	96%	72%	92%	59%		42%	83%	39%
	Yellow Freight	81%	83%	95%	99%	65%	97%	61%	89%	31%	60%	89%	64%	75%
	Ypsilanti	73%	76%	78%	95%	303%	95%	64%	92%	57%		26%	74%	75%
	Average	**80%**	**78%**	**88%**	**94%**	**106%**	**95%**	**68%**	**91%**	**49%**	**39%**	**40%**	**79%**	**52%**
Seattle	Beacon Hill	55%	45%								183%	122%	72%	73%
	Georgetown	40%	22%								170%	105%	59%	47%
	Lake Forest Park	54%	48%	86%	92%	43%	35%	60%	68%	80%	110%	70%	73%	72%
	Lake Sammamish	70%	54%	78%	98%	63%	61%	65%	86%	85%	96%	45%	88%	32%
	Maple Leaf Reservoir	60%	44%	80%	95%	54%	36%	40%	70%	61%	138%	94%	85%	53%
	Sea Tac	41%	54%	79%	96%	29%	61%	473%	66%	84%	280%	197%	73%	113%
	Average	**53%**	**45%**	**81%**	**95%**	**47%**	**48%**	**160%**	**72%**	**78%**	**163%**	**105%**	**75%**	**65%**
All	**Average**	**71%**	**67%**	**86%**	**95%**	**86%**	**79%**	**99%**	**85%**	**59%**	**105%**	**70%**	**75%**	**61%**

3.3 PREDICTIONS WITHIN A RANGE

The percent of annual average model predictions estimated within a factor of two of observations are shown in **Table 3-7** and the percent within 30% of observations is shown in **Table 3-8**. These values are less than expected based on past model evaluations of 33 city-species combinations and only eight have more than 50% of the predictions within a factor of two of the observations.

Table 3-7. Percent of predictions estimated within a factor of two of observations.

City	Acetaldehyde	Formaldehyde	Arsenic TSP	Beryllium TSP	Cadmium TSP	Chromium TSP	Lead TSP	Manganese TSP	Nickel TSP	1,3-Butadiene	Benzene	Methylene Chloride	Tetrachloroethylene
Cedar Rapids	0%	0%							0%	0%	0%	33%	0%
Detroit	0%	2%	2%	0%	38%	0%	13%	0%	52%	69%	68%	25%	82%
Seattle	36%	69%	0%	0%	56%	50%	19%	8%	4%	42%	56%	3%	69%

Table 3-8. Percent of predictions estimated within 30% of observations.

City	Acetaldehyde	Formaldehyde	Arsenic TSP	Beryllium TSP	Cadmium TSP	Chromium TSP	Lead TSP	Manganese TSP	Nickel TSP	1,3-Butadiene	Benzene	Methylene Chloride	Tetrachloroethylene
Cedar Rapids	0%	0%								0%	0%	17%	0%
Detroit	0%	1%	1%	0%	16%	0%	5%	0%	25%	43%	45%	2%	29%
Seattle	8%	39%	0%	0%	27%	23%	6%	4%	2%	15%	13%	0%	28%

3.4 RATIOS OF PREDICTED TO OBSERVED CONCENTRATIONS

It is important to stress the difference between the median and the mean of a data set. The mean gives an indication of the average value of the data, whereas the median gives an indication of how the data values are distributed within the range of the data. If the median is much lower than the mean, it gives an indication that the data set is heavily skewed to lower values, but the few higher values are dominating the average. This can be particularly evident in

observations taken close to an emissions source. **Table 3-9** shows the mean of monthly predicted to observed ratios for the species model while **Table 3-10** shows the median of the monthly ratios. With the exception of Cadmium and Chromium TSP in Detroit, and Lead in Seattle, the medians are only slightly lower than the means.

Table 3-9. Annual mean of monthly predicted to observed ratios.

City	Acetaldehyde	Formaldehyde	Arsenic TSP	Beryllium TSP	Cadmium TSP	Chromium TSP	Lead TSP	Manganese TSP	Nickel TSP	1,3-Butadiene	Benzene	Methylene Chloride	Tetrachloroethylene
Cedar Rapids	0.08	0.14								0.31	0.32	0.43	0.22
Detroit	0.20	0.22	0.12	0.06	1.42	0.05	0.34	0.09	0.69	1.29	0.70	0.30	1.25
Seattle	0.47	1.00	0.19	0.06	0.65	0.65	1.77	0.28	0.22	2.59	2.05	0.25	1.21

Table 3-10. Median of monthly predicted to observed ratios.

City	Acetaldehyde	Formaldehyde	Arsenic TSP	Beryllium TSP	Cadmium TSP	Chromium TSP	Lead TSP	Manganese TSP	Nickel TSP	1,3-Butadiene	Benzene	Methylene Chloride	Tetrachloroethylene
Cedar Rapids	0.08	0.14								0.33	0.33	0.33	0.24
Detroit	0.19	0.19	0.09	0.05	0.75	0.03	0.29	0.07	0.52	1.12	0.71	0.21	1.32
Seattle	0.42	0.89	0.18	0.05	0.55	0.51	0.47	0.24	0.18	2.31	1.92	0.21	0.95

Annual average ratios of predicted to observed concentrations were calculated three ways: (1) using the predicted at the monitoring site receptor (**Table 3-11**); (2) using the maximum predicted concentration at 25 receptors within 4.5 km of the site (**Table 3-12**); and (3) using predicted concentration at 25 receptors within 4.5 km of the site that was closest to the observed value (**Table 3-13**). A ratio of 1.0 indicates perfect agreement between the model prediction and observed values. In these tables, the ratios in *gray italics* indicate values computed with 50% or more observational data flagged as 'non-detect' and should be interpreted with caution. It is of particular note that there are significant improvements in model performance when the best-fit predictions within 4.5 km of the monitoring sites is used. Improvements are seen in species that are both over- and under-predicted at the sites. The 4.5 km search radius about the site is modest considering 1-km gridding of emissions and that these results indicate the model may be performing much better than suggested by the evaluation at the monitoring site receptors.

Table 3-11. Annual average ratios of predicted to observed concentrations.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	0.09	0.15								*0.36*	0.37	0.51	*0.25*
	Hawkeye Downs	0.07	0.13								*0.26*	0.28	0.35	*0.19*
	Average	0.08	0.14								*0.31*	0.32	0.43	*0.22*
Detroit	696_Lodge	0.27	0.37	0.24	0.10	1.61	0.04	0.52	0.12	0.48	*1.16*	1.03	0.44	*1.32*
	Allen Park	0.22	0.30	0.10	0.06	2.08	0.03	0.21	0.05	0.40	*1.22*	1.06	0.01	*1.21*
	Dearborn	0.18	0.18	0.07	0.04	0.34	0.04	0.17	0.05	0.54	*1.08*	0.70	0.13	*1.18*
	East 7 Mile	0.17	0.18	0.17	0.09	2.78	0.16	0.29	0.07	0.53				
	River Rouge	0.14	0.09	0.08	0.05	0.56	0.03	0.49	0.12	0.74	*0.69*	0.44	0.40	*1.21*
	South West HS	0.19	0.20	0.08	0.03	0.54	0.04	0.28	0.08	1.58	*2.79*	0.78	0.22	*1.47*
	Yellow Freight	0.19	0.17	0.05	0.01	0.35	0.03	0.39	0.11	0.72	*0.46*	0.11	0.38	*1.78*
	Ypsilanti	0.27	0.24	0.22	0.05	4.02	0.05	0.36	0.08	0.43	*1.63*	0.81	0.52	*0.60*
	Average	0.20	0.22	0.12	0.06	1.42	0.05	0.34	0.09	0.69	*1.29*	0.70	0.30	*1.25*
Seattle	Beacon Hill	0.45	0.66								2.83	2.22	0.28	1.49
	Georgetown	0.60	1.12								2.73	2.05	0.41	0.79
	Lake Forest Park	0.46	1.16	0.14	0.12	0.77	0.79	0.40	0.32	0.20	2.01	1.70	0.27	1.38
	Lake Sammamish	0.30	0.85	0.22	0.02	0.37	0.39	0.35	0.14	0.15	1.84	1.42	0.12	0.81
	Maple Leaf Reservoir	0.40	0.74	0.20	0.05	0.51	0.83	0.60	0.30	0.39	2.35	1.94	0.15	0.77
	Sea Tac	0.59	1.45	0.21	0.05	0.93	0.60	5.73	0.35	0.16	3.80	2.97	0.27	2.06
	Average	0.47	1.00	0.19	0.06	0.65	0.65	1.77	0.28	0.22	2.59	2.05	0.25	1.21
All	**Average**	0.29	0.50	0.14	0.06	1.16	0.26	0.83	0.15	0.53	1.68	1.19	0.30	1.10

Table 3-12. Annual ratios of maximum predicted to observed concentrations.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	0.10	0.20								*0.87*	0.68	1.15	*0.97*
	Hawkeye Downs	0.09	0.18								*0.69*	0.56	0.95	*0.96*
	Average	0.10	0.19								*0.78*	0.62	1.05	*0.97*
Detroit	696_Lodge	0.27	0.37	0.27	0.16	2.67	0.05	0.56	0.13	0.65	*1.16*	1.03	0.47	*1.46*
	Allen Park	0.26	0.34	0.10	0.07	3.52	0.05	0.32	0.10	0.54	*1.45*	1.16	0.01	*1.36*
	Dearborn	0.24	0.28	0.08	0.04	0.67	0.05	0.54	0.12	3.85	*1.96*	1.11	0.13	*1.25*
	East 7 Mile	0.26	0.32	0.39	0.28	10.32	0.56	0.88	0.11	0.95				
	River Rouge	0.23	0.19	0.11	0.08	0.91	0.07	1.06	1.14	3.54	*2.22*	1.05	0.45	*1.55*
	South West HS	0.25	0.29	0.10	0.05	1.23	0.06	1.37	1.28	7.83	*4.95*	1.23	0.44	*2.30*
	Yellow Freight	0.29	0.31	0.07	0.02	0.72	0.08	1.73	0.95	7.86	*1.22*	0.22	0.38	*2.01*
	Ypsilanti	0.29	0.29	0.37	0.14	8.30	0.21	0.86	0.12	0.69	*2.12*	1.00	0.62	*0.91*
	Average	0.26	0.30	0.19	0.10	3.54	0.14	0.91	0.49	3.24	*2.15*	0.97	0.36	*1.55*
Seattle	Beacon Hill	0.91	1.83								5.77	2.73	0.42	2.22
	Georgetown	0.93	1.33								3.12	2.21	0.41	0.92
	Lake Forest Park	0.46	1.18	0.14	0.13	0.87	0.87	0.59	0.45	0.35	2.01	1.70	0.28	1.47
	Lake Sammamish	0.33	1.16	0.26	0.09	0.79	0.70	0.44	0.19	0.19	2.43	1.89	0.20	1.53
	Maple Leaf Reservoir	0.44	1.01	0.23	0.15	1.35	1.60	0.84	0.62	0.77	3.28	2.60	0.20	1.57
	Sea Tac	1.14	3.46	0.22	0.12	1.16	0.73	26.57	0.70	0.24	7.62	3.37	0.29	2.28
	Average	0.70	1.66	0.21	0.12	1.04	0.97	7.11	0.49	0.39	4.04	2.42	0.30	1.66
All	**Average**	0.41	0.80	0.19	0.11	2.71	0.42	2.98	0.49	2.29	2.72	1.50	0.43	1.52

Table 3-13. Annual ratios of best predicted to observed concentrations.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	0.10	0.20								*0.87*	0.68	0.94	*0.97*
	Hawkeye Downs	0.09	0.18								*0.69*	0.56	0.95	*0.96*
	Average	0.10	0.19								*0.78*	0.62	0.94	*0.97*
Detroit	696_Lodge	0.27	0.37	0.27	0.16	1.22	0.05	0.56	0.13	0.65	*0.98*	1.03	0.47	*1.04*
	Allen Park	0.26	0.34	0.10	0.07	1.00	0.05	0.32	0.10	0.54	*0.98*	0.99	0.01	*0.95*
	Dearborn	0.24	0.28	0.08	0.04	0.67	0.05	0.54	0.12	0.92	*0.99*	1.00	0.13	*0.95*
	East 7 Mile	0.26	0.32	0.39	0.28	1.02	0.56	0.88	0.11	0.95				
	River Rouge	0.23	0.19	0.11	0.08	0.91	0.07	0.96	1.14	0.99	*1.00*	1.05	0.45	*1.01*
	South West HS	0.25	0.29	0.10	0.05	0.85	0.06	0.73	1.28	0.96	*1.03*	0.96	0.44	*0.99*
	Yellow Freight	0.29	0.31	0.07	0.02	0.72	0.08	0.52	0.95	0.89	*0.96*	0.22	0.38	*1.03*
	Ypsilanti	0.29	0.29	0.37	0.14	1.22	0.21	0.86	0.12	0.69	*1.01*	1.00	0.62	*0.91*
	Average	0.26	0.30	0.19	0.10	0.95	0.14	0.67	0.49	0.82	*0.99*	0.89	0.36	*0.98*
Seattle	Beacon Hill	0.91	0.83								1.39	1.29	0.42	1.00
	Georgetown	0.93	1.00								0.97	1.04	0.41	0.92
	Lake Forest Park	0.46	1.06	0.14	0.13	0.87	0.87	0.59	0.45	0.35	0.98	0.99	0.28	0.96
	Lake Sammamish	0.33	0.99	0.26	0.09	0.79	0.70	0.44	0.19	0.19	1.00	1.00	0.20	1.03
	Maple Leaf Reservoir	0.44	1.01	0.23	0.15	1.02	0.97	0.84	0.62	0.77	1.16	1.15	0.20	0.98
	Sea Tac	1.09	1.00	0.22	0.12	1.00	0.73	1.07	0.70	0.24	1.37	1.55	0.29	1.14
	Average	0.69	0.98	0.21	0.12	0.92	0.81	0.74	0.49	0.39	1.15	1.17	0.30	1.01
All	**Average**	0.40	0.54	0.19	0.11	0.94	0.37	0.69	0.49	0.68	1.02	0.97	0.41	0.99

3.5 SCATTER PLOTS

Scatter plots of predicted versus observed concentrations are shown for each species modeled in **Figures 3-1 to 3-13**. In each figure the plot on the left side (a) compares the annual average observations and predictions and the plot on the right side (b) compares monthly averages. All sites in all three cities are plotted with unique colors and symbols for each city so similarities and differences between cities can be seen. In these figures the following notation is used for city names: CDR for Cedar Rapids, DET for Detroit, and SEA for Seattle.

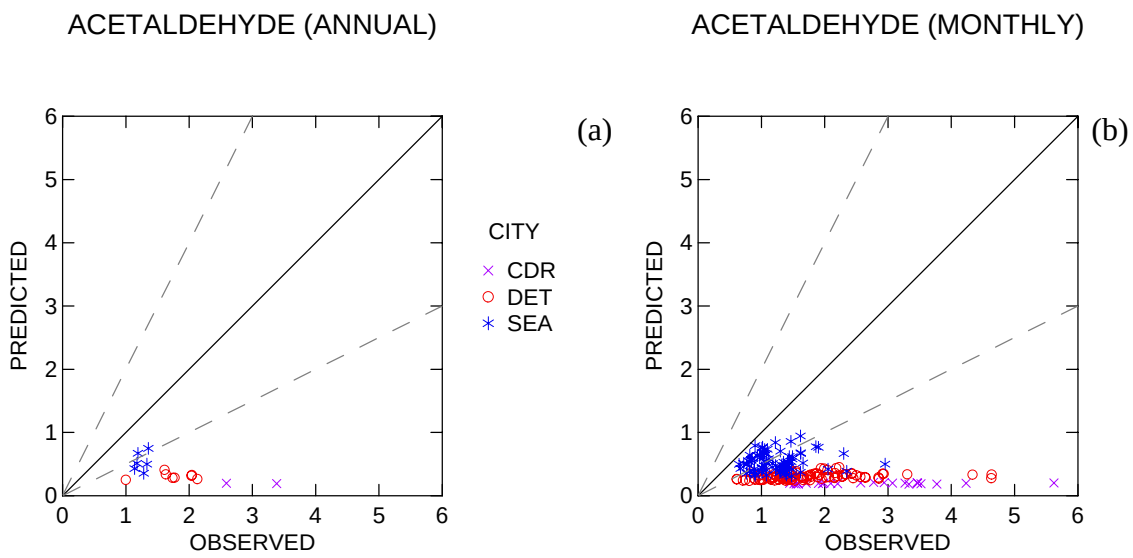

Figure 3-1. Predicted vs. observed acetaldehyde concentrations (µg/m^3) annual (a) and monthly (b) values. One value for CDR with observed concentration > 10 µg/m^3 was omitted from the monthly plot.

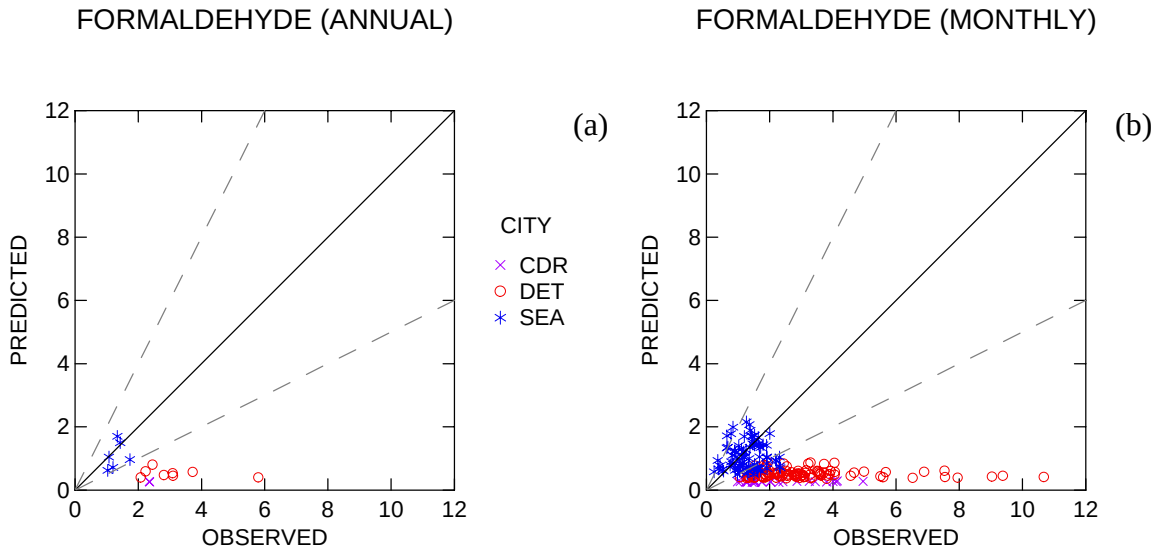

Figure 3-2. Predicted vs. observed formaldehyde concentrations (µg/m^3) annual (a) and monthly (b) values.

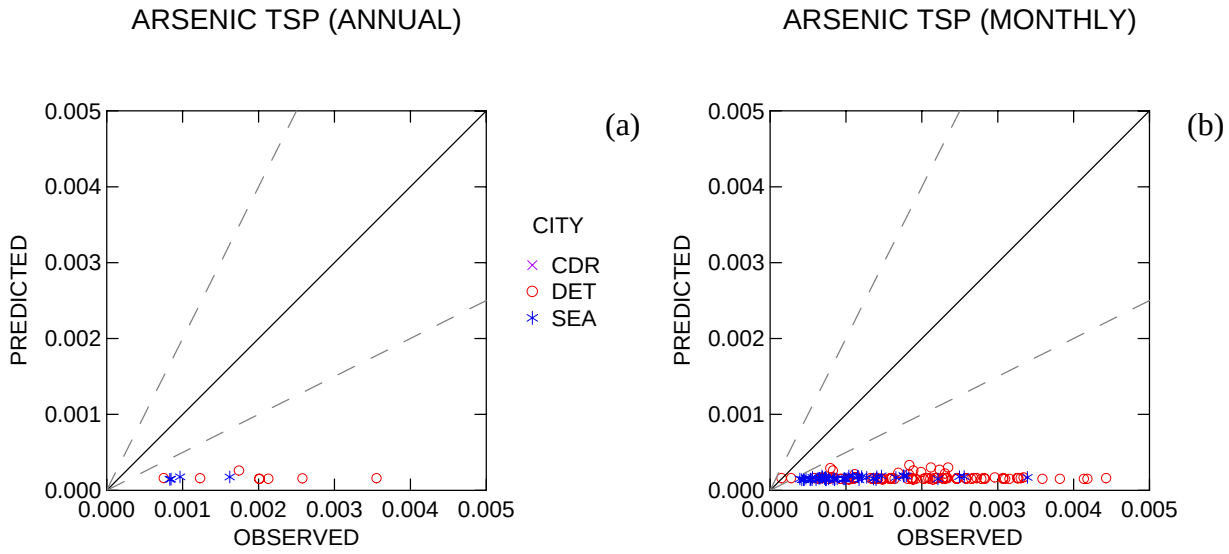

Figure 3-3. Predicted vs. observed arsenic TSP concentrations (µg/m^3) annual (a) and monthly (b) values. One value for DET with observed concentration > 0.005 µg/m^3 was omitted from the monthly plot.

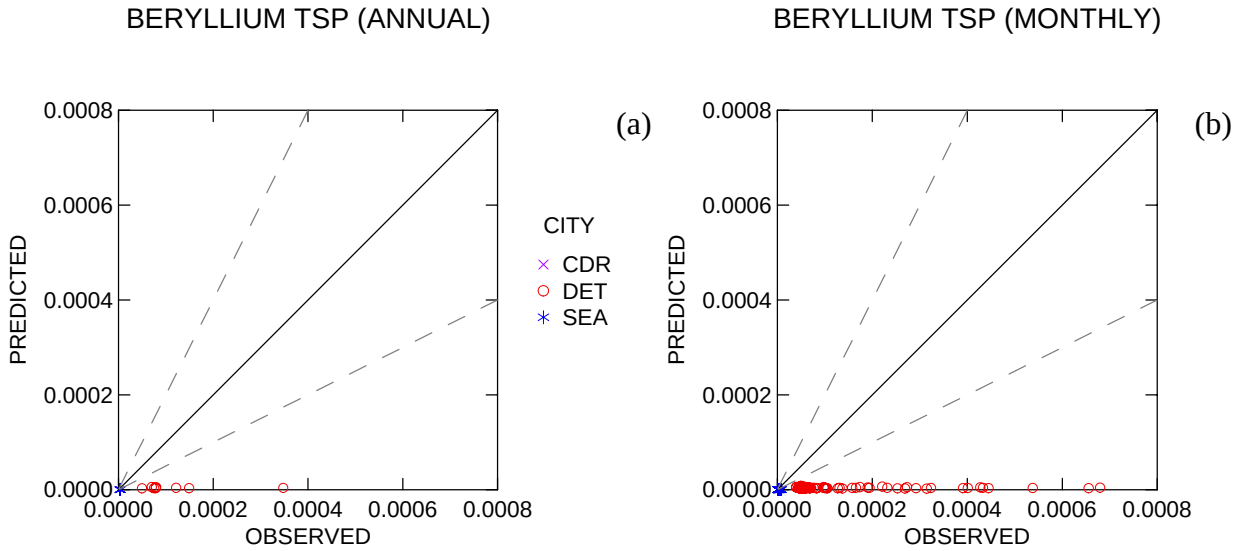

Figure 3-4. Predicted vs. observed beryllium TSP concentrations (µg/m^3) annual (a) and monthly (b) values.

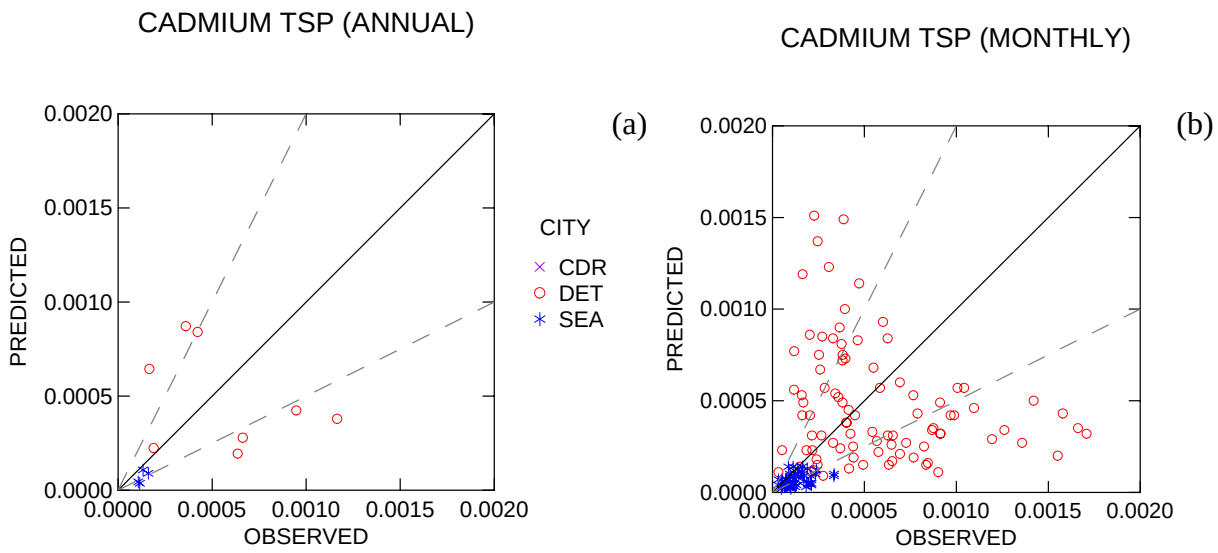

Figure 3-5. Predicted vs. observed cadmium TSP concentrations (µg/m^3) annual (a) and monthly (b) values. One value for DET with an observed concentration > 0.002 µg/m^3 was omitted from the monthly plot.

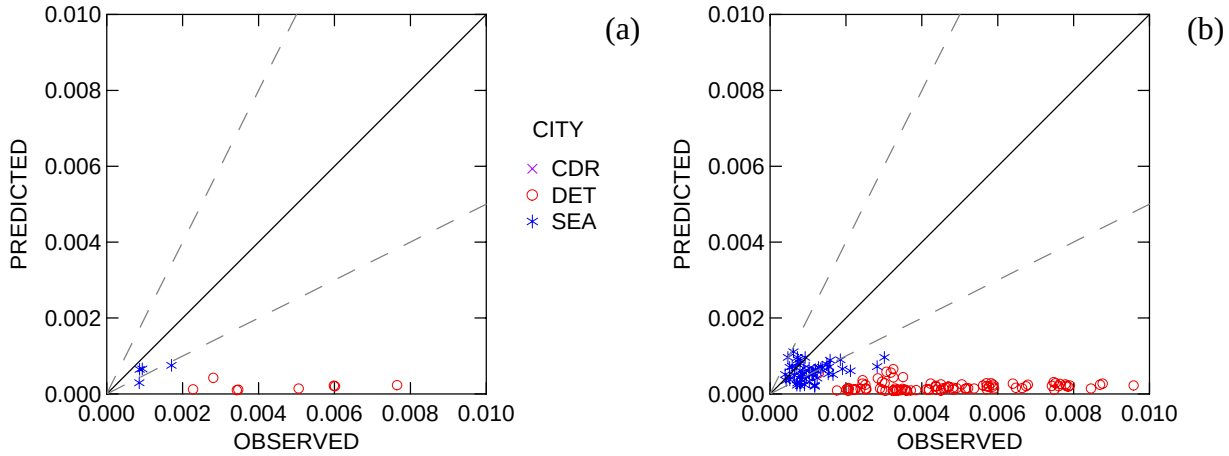

Figure 3-6. Predicted vs. observed chromium TSP concentrations (µg/m^3) annual (a) and monthly (b) values. One value for DET with an observed concentration > 0.01 µg/m^3 was omitted from the monthly plot.

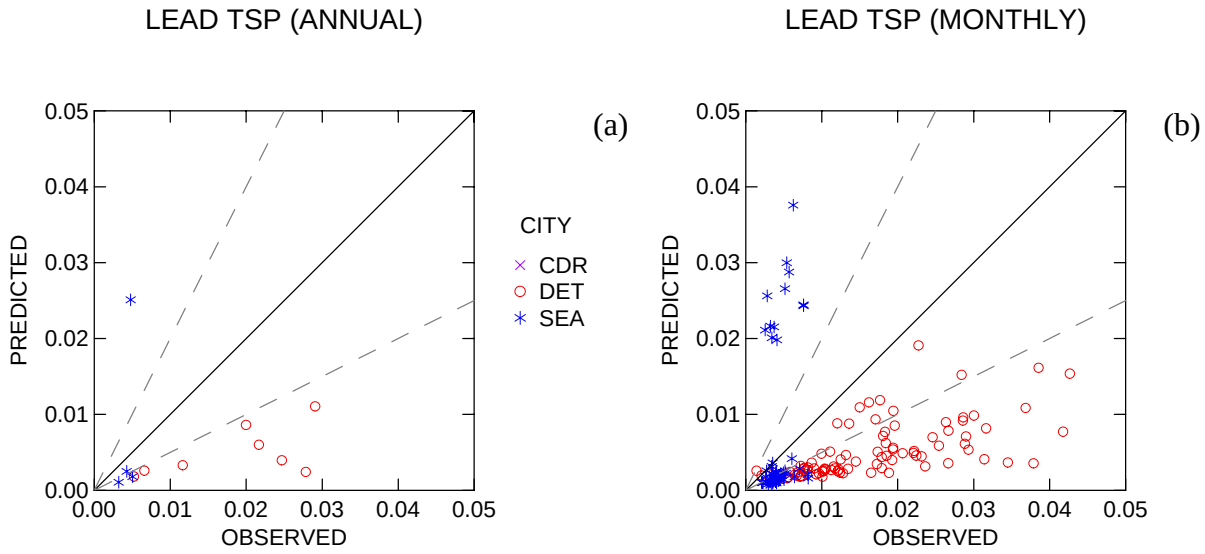

Figure 3-7. Predicted vs. observed lead TSP concentrations (µg/m^3) annual (a) and monthly (b) values. One value for DET with observed concentration > 0.05 µg/m^3 was omitted from the monthly plot.

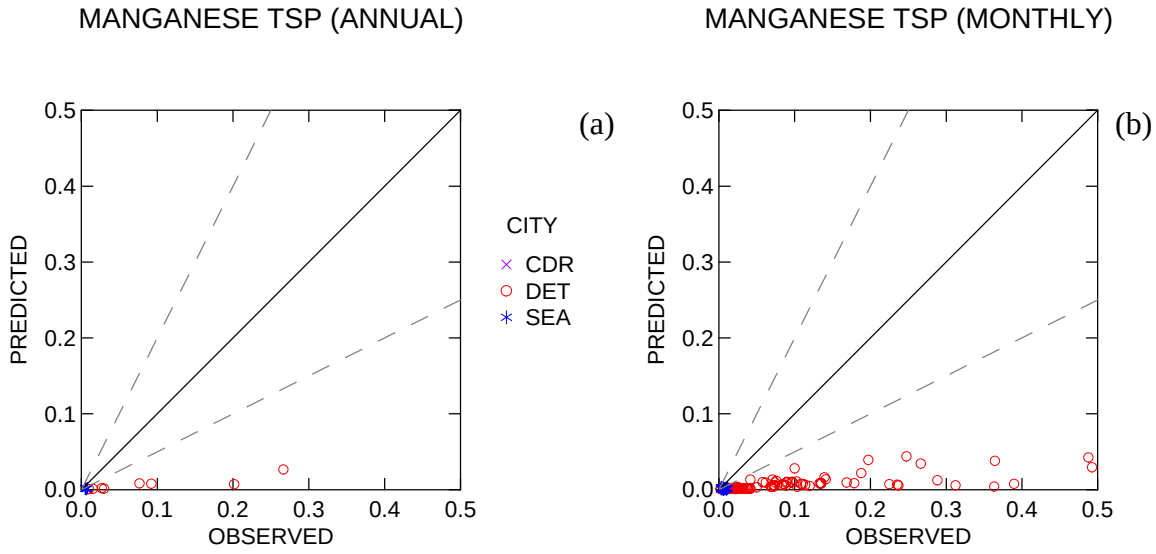

Figure 3-8. Predicted vs. observed manganese TSP concentrations (µg/m^3) annual (a) and monthly (b) values.

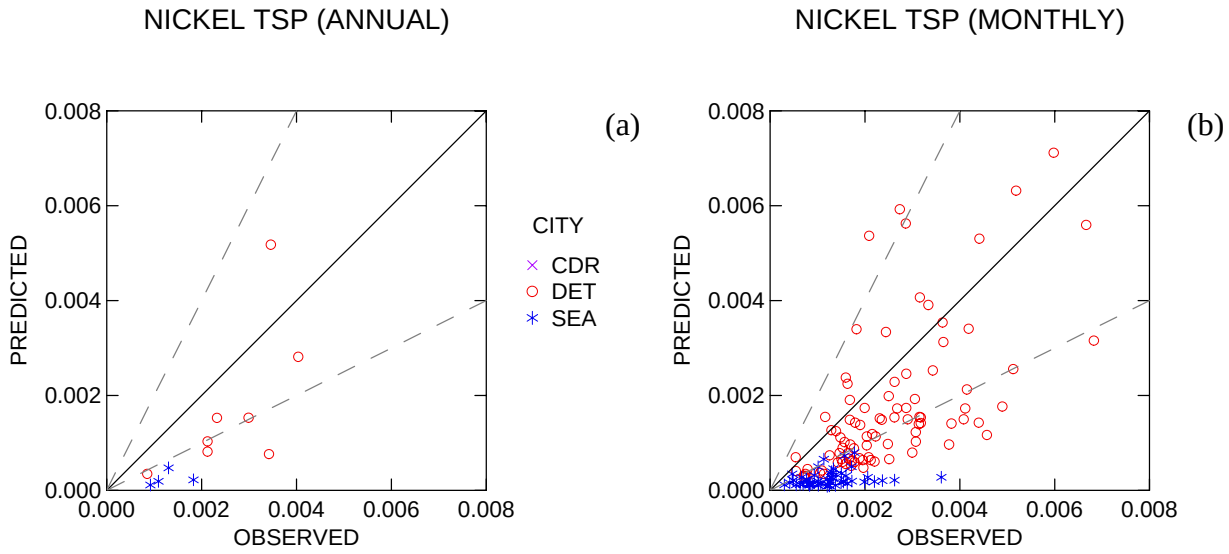

Figure 3-9. Predicted vs. observed nickel TSP concentrations (µg/m^3) annual (a) and monthly (b) values. One value for DET with observed concentration > 0.008 µg/m^3 was omitted from the monthly plot.

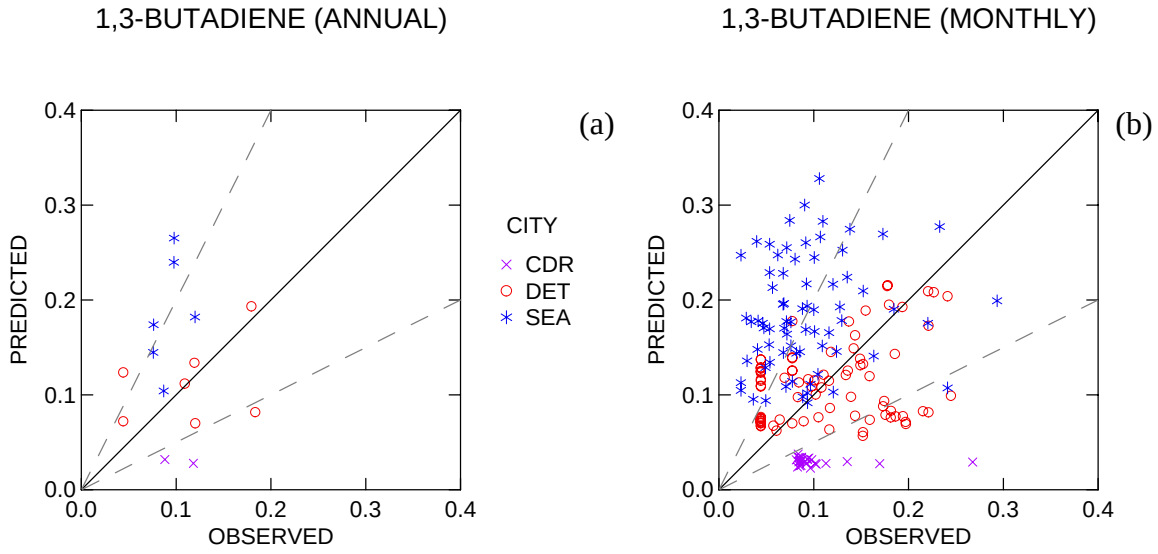

Figure 3-10. Predicted vs. observed 1,3-butadiene concentrations (µg/m^3) annual (a) and monthly (b) values.

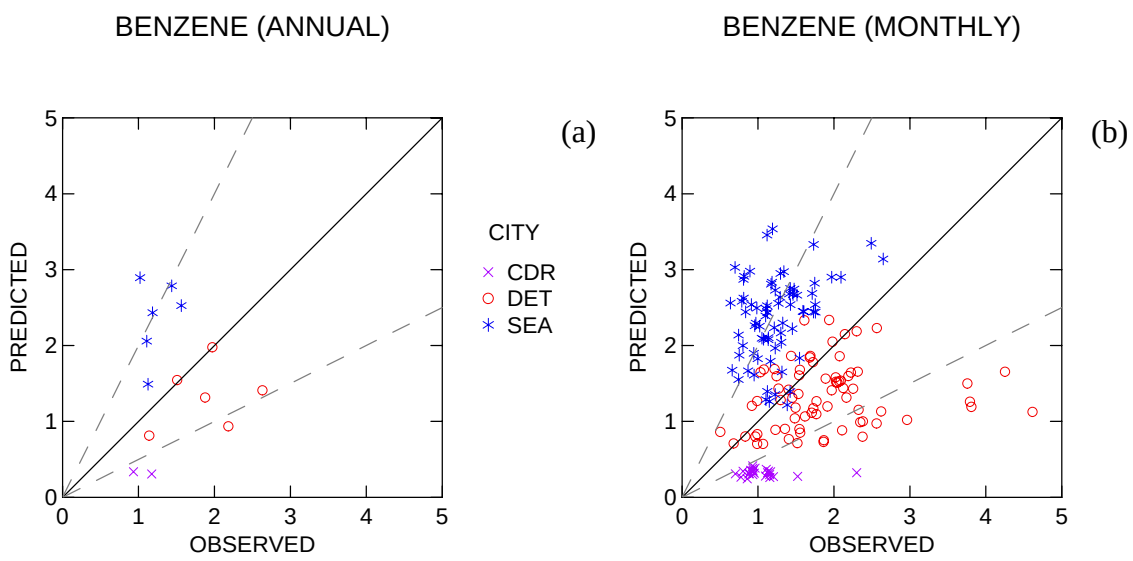

Figure 3-11. Predicted vs. observed benzene concentrations (µg/m^3) annual (a) and monthly (b) values. Eleven values for DET with observed concentrations > 5 µg/m^3 were omitted from the monthly plot and one value for DET with observed concentration > 5 µg/m^3 was omitted from the annual plot.

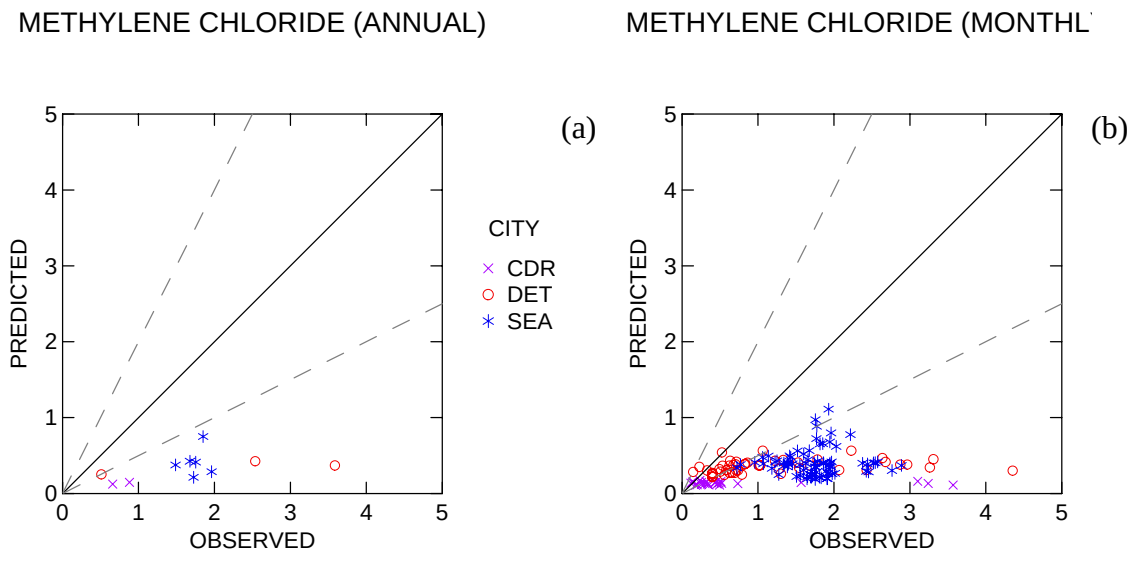

Figure 3-12. Predicted vs. observed methylene chloride concentrations (µg/m^3) annual (a) and monthly (b) values. Approximately 30 values for DET with observed concentrations > 5 µg/m^3 were omitted from the monthly plot and one value for DET with observed concentration > 5 µg/m^3 was omitted from the annual plot.

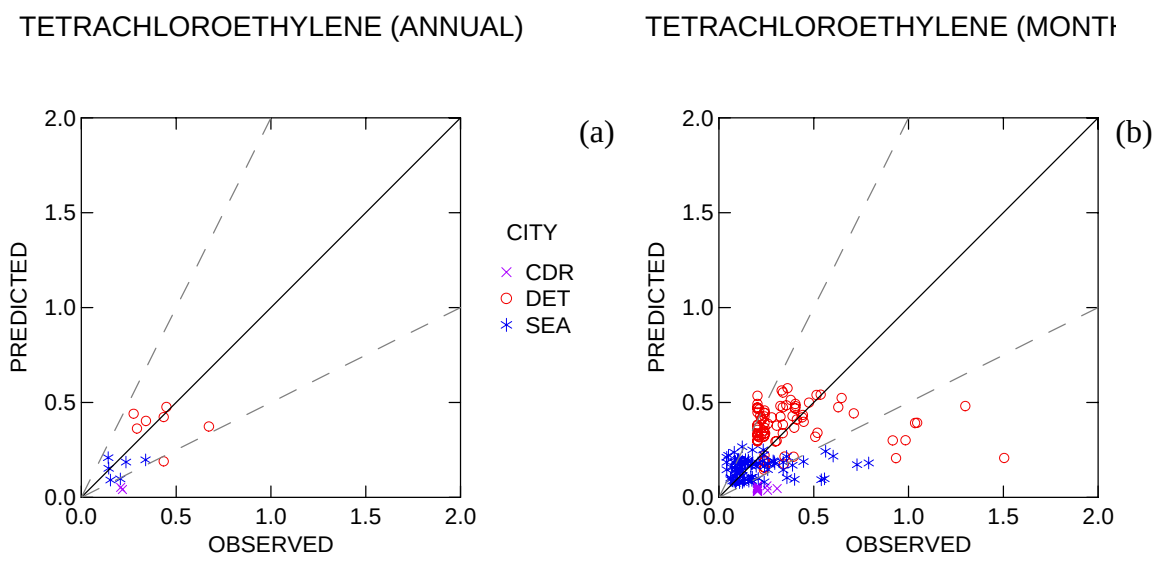

Figure 3-13. Predicted vs. observed tetrachloroethylene concentrations (µg/m^3) annual (a) and monthly (b) values. One value for DET with observed concentration > 2.0 µg/m^3 was omitted from the monthly plot.

3.6 BOX-WHISKER PLOTS

Box-whisker plots of monthly-average, model-predicted to observed concentration rations are shown for Cedar Rapids, Detroit, and Seattle in **Figures 3-14, 3-15, and 3-16** respectively. A composite plot showing all three cities together is provided in **Figure 3-17**. In these box-whisker plots, the top and bottom edges of each box represent the 75th and 25th percentiles of the monthly values, with the center line denoting the median. Box whiskers indicate the extent of values within 1.5 times the inter-quartile range, the asterisks denote data within 3 times the inter-quartile range, and circles indicate outliers.

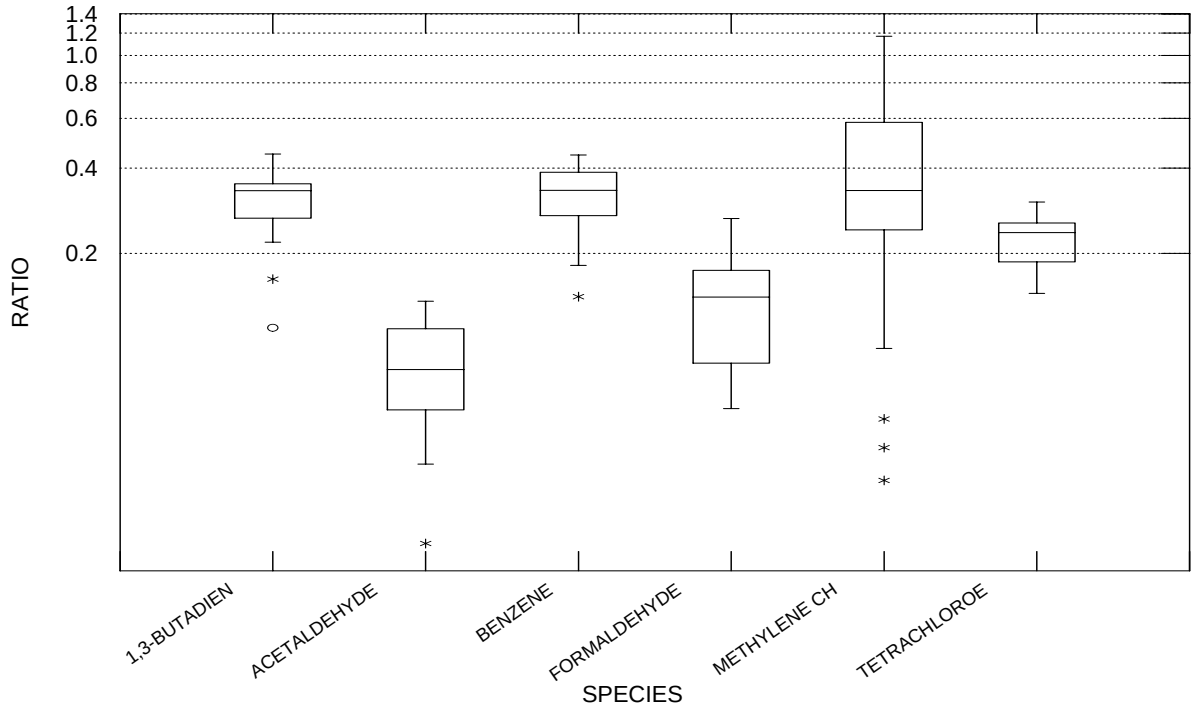

Figure 3-14. Predicted to observed concentration ratios for Cedar Rapids.

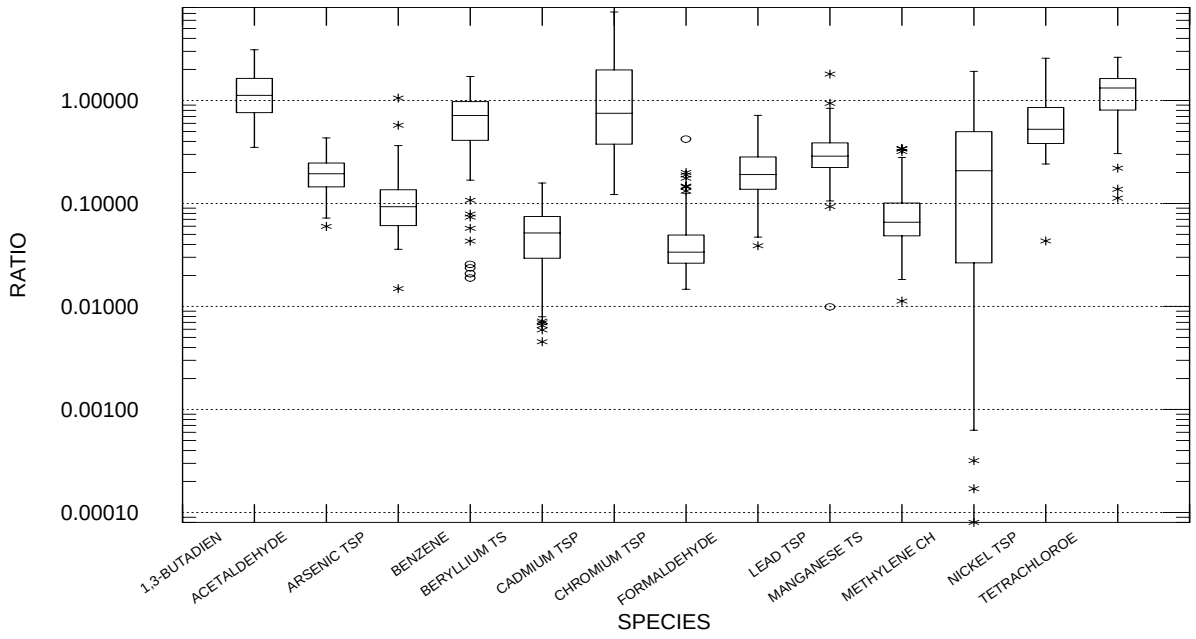

Figure 3-15. Predicted to observed concentration ratios for Detroit.

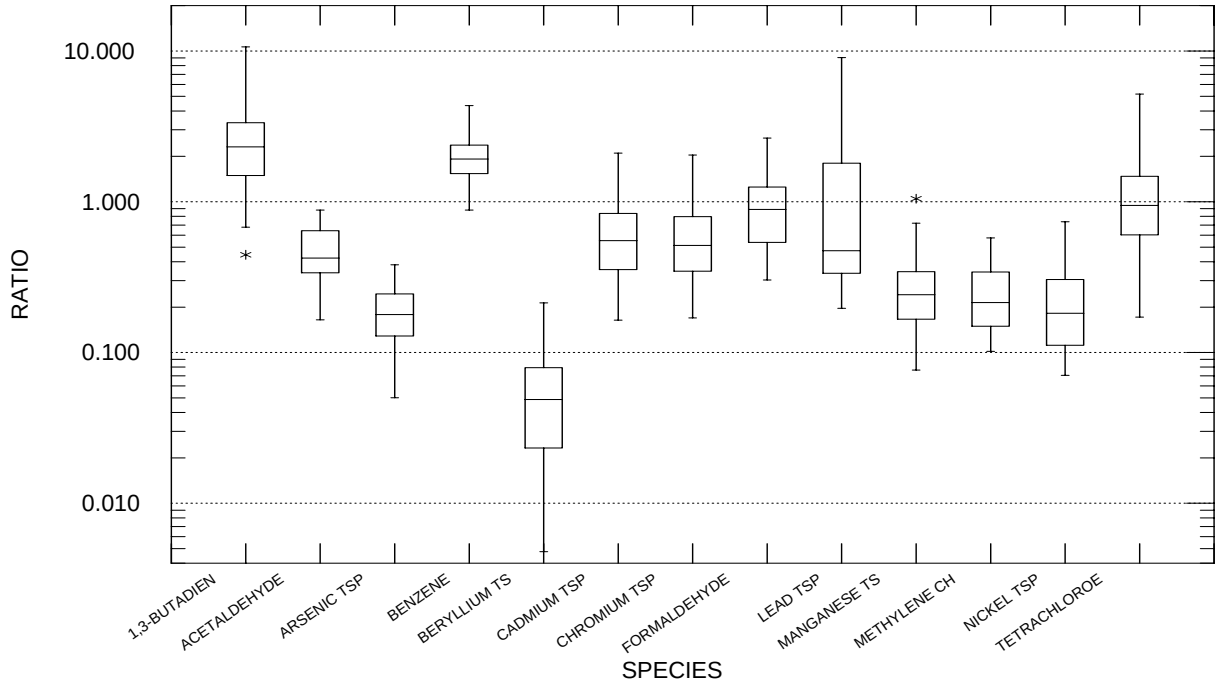

Figure 3-16. Predicted to observed concentration ratios for Seattle.

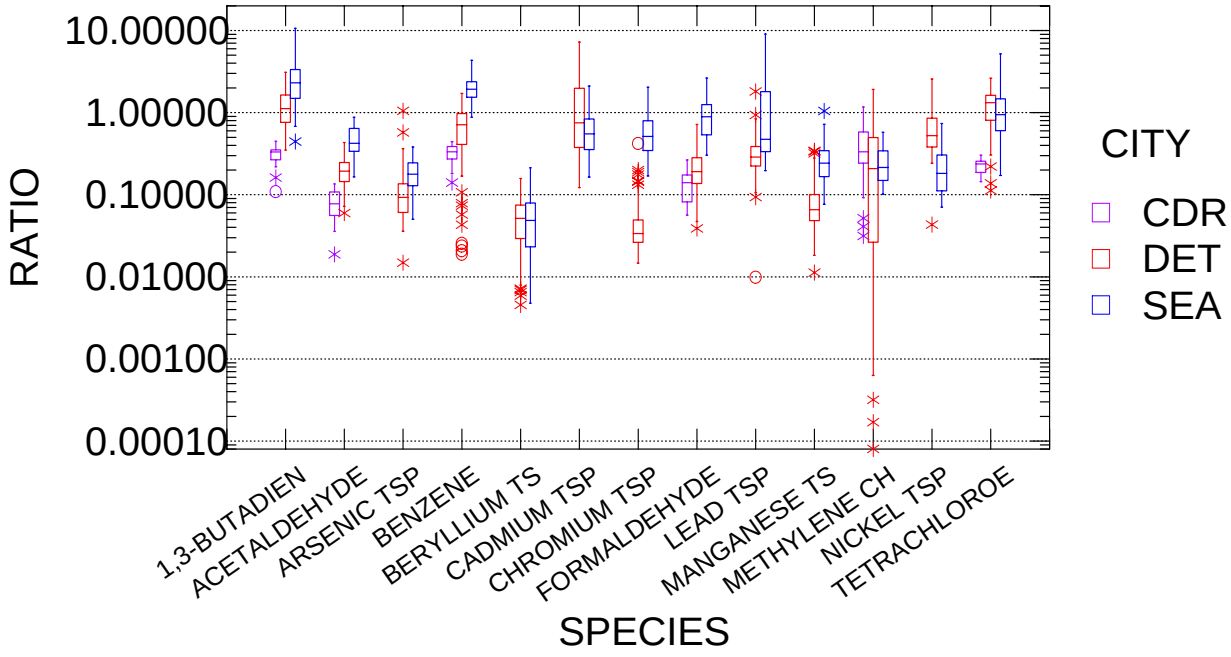

Figure 3-17. Predicted to observed concentration ratios for all cities.

3.7 MONTHLY VARIATIONS IN MODEL PERFORMANCE

For most species and locations there appears to be little variation in model performance by month. However, seasonal variations did occur for a few sites and species. **Figure 3-18** shows the monthly variation in the ratio of predicted (primary only) to observed average formaldehyde concentrations for each of the three cities. Seattle does not demonstrate the expected level of underprediction when not considering secondary formation and shows a large overprediction in early autumn. It is suspected that the general overprediction is due to sources in the emissions inventory used as inputs to the modeling near the location of the monitors and that the larger overpredictions result from changes in wind direction.

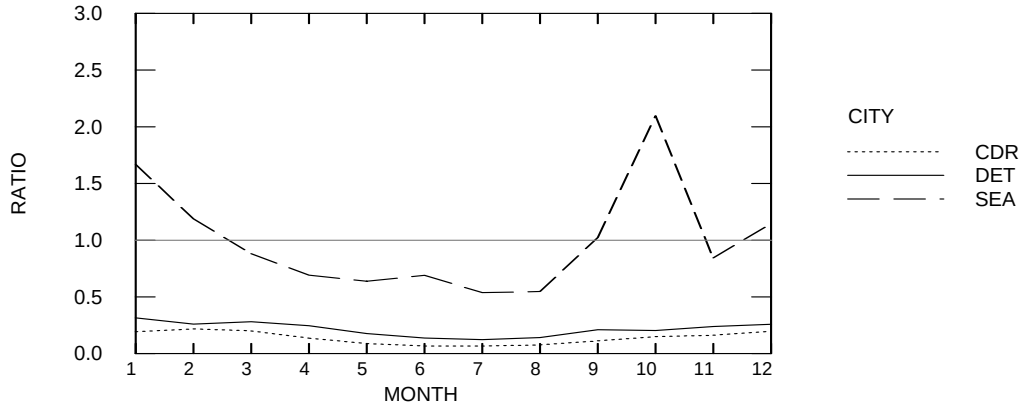

Figure 3-18. Monthly average prediction to observed concentration ratios for formaldehyde.

In **Figure 3-19** we see a general overprediction of 1,3-butadiene in Detroit and Seattle with the greatest overpredictions occurring during the summer months even though we are specifying a half-life that is 25% of that used for winter months. These two cities are dominated by motor vehicle emissions and it may be that the estimates of 1,3-butadiene's reactivity are overly conservative and need to be city- and month-specific instead of seasonal for all cities.

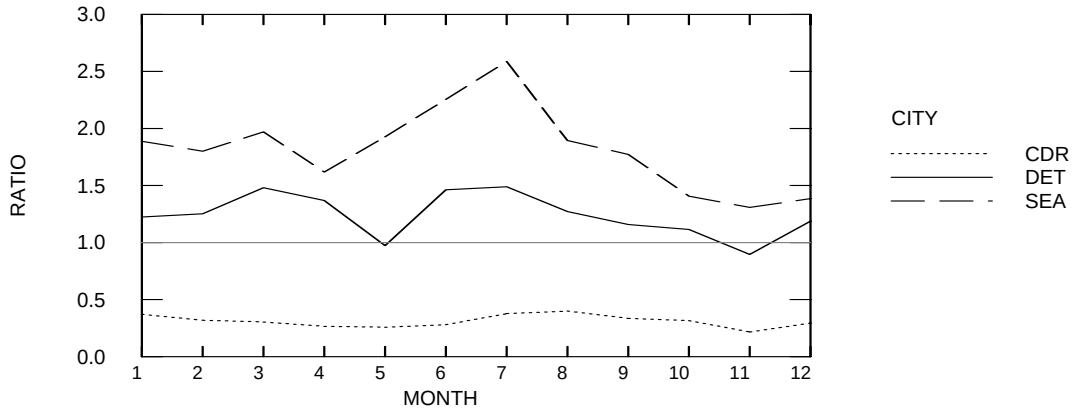

Figure 3-19. Monthly average prediction to observed concentration ratios for 1,3-butadiene.

Plots showing the monthly variation in prediction to observed concentration ratios for all species modeled are provided in Appendix B.

3.8 SECONDARY FORMATION OF SPECIES

EPA estimates of secondary acetaldehyde and formaldehyde production from OZIPR model runs for 10 cities (U.S. Environmental Protection Agency, 1999b) indicated that 87% to 92% of acetaldehyde and formaldehyde were the result of secondary formation. Based on these results, the EPA suggested that if none of the cities in this report typifies the area of interest, the secondary component of the HAPs concentrations may be estimated from values for the primary component. For formaldehyde and acetaldehyde, the EPA recommended multiplying the spatial average primary concentrations by 9.0 (90%/10%) to estimate the secondary contribution to these species and then to add that concentration to the site-specific primary concentrations. The calculations are provided in **Table 3-14**. Applying this methodology to the cities in this study resulted in large overpredictions (some exceeding 1000%) at most sites in Detroit and Seattle. For Cedar Rapids, acetaldehyde was underpredicted by 34% and formaldehyde was overpredicted by 15% using this method.

Table 3-14. Evaluation of model performance including estimates of secondary acetaldehyde and formaldehyde production. Concentrations are annual averages in $\mu g/m^3$.

City	Site	Primary Predicted Concentration		Secondary Predicted Concentration		Total Predicted Concentration		Observed Concentration		Ratio of Predicted to Observed Concentration	
		Acetaldehyde	Formaldehyde	Acetaldehyde	Formaldehyde	Acetaldehyde	Formaldehyde	Acetaldehyde	Formaldehyde	Acetaldehyde	Formaldehyde
Cedar Rapids	Army Reserve	0.20	0.27	1.78	2.43	1.97	2.71	2.59	2.35	0.76	1.15
	Hawkeye Downs	0.19	0.26	1.74	2.33	1.93	2.59	3.38	2.36	0.57	1.10
	Average	0.20	0.26	1.76	2.38	1.95	2.65	2.99	2.35	0.65	1.13
Detroit	696_Lodge	0.41	0.80	3.67	7.22	4.08	8.03	1.61	2.45	2.53	3.28
	Allen Park	0.34	0.59	3.04	5.31	3.37	5.90	1.63	2.23	2.07	2.65
	Dearborn	0.31	0.53	2.82	4.80	3.14	5.34	2.04	3.09	1.54	1.73
	East 7 Mile	0.28	0.47	2.56	4.27	2.84	4.74	1.77	2.81	1.60	1.69
	River Rouge	0.26	0.40	2.37	3.61	2.63	4.01	2.13	5.80	1.23	0.69
	South West HS	0.33	0.57	2.94	5.16	3.27	5.73	2.04	3.72	1.60	1.54
	Yellow Freight	0.28	0.45	2.53	4.07	2.81	4.52	1.74	3.10	1.62	1.46
	Ypsilanti	0.25	0.40	2.24	3.60	2.49	4.00	1.00	2.08	2.49	1.92
	Average	0.31	0.53	2.77	4.76	3.08	5.28	1.75	3.16	1.76	1.67
Seattle	Beacon Hill	0.50	0.96	4.49	8.68	4.99	9.65	1.33	1.73	3.75	5.58
	Georgetown	0.67	1.50	6.04	13.51	6.71	15.01	1.19	1.43	5.64	10.50
	Lake Forest Park	0.51	1.04	4.60	9.38	5.12	10.43	1.18	1.07	4.33	9.74
	Lake Sammamish	0.35	0.62	3.19	5.60	3.54	6.22	1.28	1.03	2.77	6.04
	Maple Leaf Reservoir	0.43	0.72	3.85	6.45	4.28	7.17	1.14	1.20	3.76	5.98
	Sea Tac	0.75	1.70	6.74	15.31	7.49	17.01	1.36	1.34	5.50	12.70
	Average	0.54	1.09	4.82	9.82	5.35	10.92	1.25	1.30	4.28	8.40
All	Average	0.38	0.71	3.41	6.36	3.79	7.07	1.71	2.36	2.22	2.99

4. SUMMARY AND DISCUSSION OF RESULTS

4.1 MODEL PERFORMANCE

TSP metals estimates were only available for Seattle and Detroit, and were generally underpredicted except for cadmium. Predictions of arsenic, beryllium, and manganese were the least accurate, with underpredictions of 85-94% on average at the monitoring sites. Lead was undepredicted by 66% on average in Detroit but overpredicted by 77% in Seattle, which was dominated by an overprediction at the Seattle-Tacoma airport (SeaTac) monitor of 473%. However, this overprediction may be explained by the misallocation of general aviation fuel emissions to the SeaTac airport, a situation discussed further in the following section on emission inventory quality.

Without considering secondary formation, acetaldehyde concentrations were underpredicted by 92% in Cedar Rapids, 80% in Detroit, and 53% in Seattle. Without considering secondary formation, formaldehyde concentrations were underpredicted by 86% in Cedar Rapids and 78% in Detroit. On average, Seattle showed no under or overprediction.

EPA estimates of secondary acetaldehyde and formaldehyde production from OZIPR model runs for 10 cities (U.S. Environmental Protection Agency, 1999b) indicated that 87% to 92% of acetaldehyde and formaldehyde were the result of secondary formation. Based on these results, the EPA suggested that if none of the cities in this report typifies the area of interest, the secondary component of the HAPs concentrations may be estimated from values for the primary component. For formaldehyde and acetaldehyde, the EPA recommended multiplying the spatial average primary concentrations by 9.0 (90%/10%) to estimate the secondary contribution to these species and then add that concentration to the site-specific primary concentrations. Applying this methodology to the cities in this study resulted in large overpredictions (some exceeding 1000%) at most sites in Detroit and Seattle. For Cedar Rapids, acetaldehyde was underpredicted by 34% and formaldehyde was overpredicted by 15% using this method.

1,3-Butadiene, benzene, and tetrachloroethylene are overpredicted in Detroit and Seattle, and underpredicted in Cedar Rapids. Methylene chloride is generally underpredicted, but unlike the other volatile organic compounds (VOCs) modeled, it is most accurately predicted in Cedar Rapids.

The model-predicted concentrations were generally less variable than the observations. This is consistent with distributing non-point source emissions to 1-km areas for modeling.

When the best-fit model predictions (i.e., the closest to the observed value) for receptors within 4.5 km of the monitoring sites were used, there were significant improvements in model performance.

4.2 EMISSIONS INVENTORY QUALITY

Based on model performance of the best-fit predictions, the National Emissions Inventory (NEI) appears to be of reasonable quality for the gas-phase species, except for methylene

chloride. This is consistent with many of the gaseous species being dominated by mobile sources emissions, which have undergone continuous research and improvement over the past decade. The consistent underprediction of methylene chloride across all sites indicates that a significant amount of this solvent may be missing from the emissions inventory.

Most metals have been underpredicted in past modeling studies and were underpredicted in this study. Because model predictions for some metals (e.g., cadmium) and some low-reactivity VOCs (i.e., benzene) were not underpredicted, it is believed that these are not a result of meteorological biases. These results infer that the emission inventory for most of the metals is underestimated. Improvements to inventories of toxic metals should focus initially on risk drivers such as arsenic.

Missing sources can significantly affect model performance. Extremely high concentrations (i.e., greater than 10,000 $\mu g/m^3$) of methylene chloride were measured at the Allen Park site in Detroit, which dominated the annual average concentration. The emissions inventory contained only known sources of these emissions and the model predicted only 1% of the observed annual average.

Care must be taken in the selection of spatial surrogates. The overprediction of lead TSP at the SeaTac site in Seattle was found to be a result of lead emission from general aviation fuel being allocated to all airports based on their spatial size. Instead of allocating these emission, which make up 98% of the lead emissions for the modeling domain, to dozens of small general aviation airports, most of the emissions were allocated to the SeaTac airport, which is upwind of the SeaTac monitor, and to Boeing Field, which is downwind of the monitor. It is noted that general aviation fuels currently contain lead but that low-lead fuels (approximately 25% of the original lead content) have been introduced in the past decade. Future modeling studies should verify that current speciation profiles for general aviation fuels are used.

Allocation of mobile source emissions to 1-km areas for modeling was not sufficient to resolve concentration gradients near roadways. For example:

- Mobile-source-related species were significantly overpredicted at the SeaTac monitoring site in Seattle. While the SeaTac monitor is upwind of major roadways, emissions from those roadways were allocated to the 1-km area in which the monitor was located.
- Mobile-source-related species were significantly underpredicted at the two monitoring sites in Cedar Rapids. Both sites are relatively near interstate highways that appear to have a larger impact on the monitors than is estimated by the model when those emissions are spread over a 1-km area.

These results indicate that it may be more difficult to model mobile sources in smaller cities where emissions are less ubiquitous, and in areas where sites are located at the upwind edge of the city, than in larger cities.

4.3 BACKGROUND CONCENTRATIONS

Models require operational background concentrations, which consist of global background concentrations plus regional, natural, and upwind sources of pollutants. For some

locations and species, there are measurements sufficient to establish operational background concentrations. However, as is the case in this study, there are insufficient measurements for most cities and species.

Regional background concentrations may be estimated from rural monitoring stations for compounds with relatively long atmospheric residence times. However, air toxics monitoring has historically focused on areas where there is likely to be higher levels of human exposure. This focus has not provided adequate measurements to establish regional background concentrations of air toxics for use in modeling assessments.

Upwind monitoring stations, chemical lifetimes, and ambient monitoring data can be used to help identify operational background concentrations on a site-by-site basis. However, few monitoring stations are always upwind of a site.

The remote background concentrations routinely measured at NOAA CMDL monitoring stations provide reasonable estimates of global background concentrations and can provide reasonable estimates of regional background for species that currently have no significant sources of emissions in the United States (e.g., carbon tetrachloride) or that are removed rapidly from the atmosphere (e.g., 1,3-butadiene).

Establishing boundary conditions is complicated because some important toxics (e.g., benzene, formaldehyde, 1,3-butadiene, and acetaldehyde) undergo chemical transformation in the atmosphere. Further complications exist because formaldehyde and acetaldehyde can be formed from every VOC in the atmosphere. Major contributors to aldehyde formation are toluene, xylenes, other hydrocarbons present in automobile exhaust, and biogenic hydrocarbons. It is estimated that more than 80% of these aldehydes may be due to atmospheric formation, not emissions (Luecken, 2002).

Photochemical grid models can be used to establish regional and urban-scale operational background concentrations for both reactive and non-reactive species. While photochemical grid models require considerable resources to setup, run, and evaluate, representing the secondary formation of risk drivers such as formaldehyde and acetaldehyde properly will be necessary before air quality models can become useful planning tools. However, rural measurements will still be needed to validate regional photochemical models.

4.4 COMPLEX METEOROLOGY, TERRAIN, AND EMISSIONS PATTERNS

While these impacts were not explicitly investigated in this study, some information about these impacts can be inferred from the differences between sites and cities. Many cities have meteorology that is influenced by terrain or water bodies resulting in spatial variations of wind direction and speed, temperature, moisture, and vertical mixing across the city. For those cities, the use of single-station meteorology, as used in this study, cannot adequately represent the transport, diffusion, transformation, and removal processes affecting concentrations of HAPs. For example, winds are typically from the south-southwest in southern Seattle, southerly in central Seattle, and southeasterly in northern Seattle. Therefore, using the winds from any one area will be incorrect for the others.

The gradients in modeled concentrations near monitoring sites indicate that while a model may accurately predict near-site concentrations, it may not predict the concentrations in the correct location. This may be a result of meteorological complexity (the meteorology used in the model is not representative of all locations) or emissions complexity (cases with many industrial point sources or spatial allocation of non-point sources by spatial surrogates). While this may not be an issue for criteria pollutants where maximum concentrations are of concern, HAPs need to be evaluated in terms of population exposure. Failure to get concentrations in the correct locations may result in any exposure estimates being useless for planning purposes.

4.5 MODEL USE IN AIR TOXICS PLANNING

To use modeling tools in air toxics planning means to use their predictive capabilities to assess the effectiveness of potential control measures in reducing exposure to HAPs.

For cases where species are non-reactive, emissions are well-known, and meteorology does not spatially vary significantly, the tools used in this study may be appropriate for planning purposes. However, in such cases, simpler approaches such as linear rollback may be as effective for planning purposes. For cases where meteorological complexity is an issue, the tools used in this study have limited applicability for planning purposes because of their inability to use varying meteorology needed to properly estimate the exposure to HAPs. For cases with significant contributions of HAPs from sources beyond the 50-km modeling domain (e.g. the transport of benzene from major upwind cities), the tools used in this study are insufficient for use in air toxics planning.

For cases where secondary formation of HAPs is being addressed, the tools used in this study may have limited usefulness. The simplified approach for estimating secondary production of HAPs using the OZIPR model was found to be inadequate in some areas because it does not take into account monitor location relative to areas of precursor emissions. This can lead to significant overestimation of secondary HAPs at some locations. In Seattle, for example, the OZIPR estimated secondary formaldehyde and acetaldehyde concentrations alone were three and ten times the observed concentrations, respectively. Because these species are considered risk drivers, care should be taken to accurately model their secondary formation.

5. CONCLUSIONS

In this study, 13 HAPs were predicted for Detroit, Seattle, and Cedar Rapids with the ISCST3 model using single station meteorology for each city, and emissions from the NEI. The model predictions were evaluated using observations from the pilot-city database. Based on the evaluations performed, a series of policy relevant questions were answered to the extent possible. Those questions and their answers are summarized below.

How robust was the modeling approach used in this study?

Figure 5-1 provides an overview of model performance in terms of the ratio of model-predicted to observed concentrations for each city and species modeled. A ratio of 1.0 indicates perfect agreement between the model and observations. Values less than 1.0 indicate underprediction by the model and ratios greater than 1.0 indicate overpredictions. The following is a general description of those results:

- TSP metals (Seattle and Detroit only) were generally underpredicted except for cadmium. Predictions of arsenic, beryllium, and manganese were the least accurate.
- Lead was undepredicted in Detroit but overpredicted in Seattle, which was dominated by an overprediction at the SeaTac monitor. However, this overprediction may be explained by the misallocation of general aviation fuel emissions to the SeaTac airport, a situation discussed further in the following question concerning emission inventory quality.
- Without considering secondary formation, acetaldehyde concentrations were underpredicted Seattle. Without considering secondary formation, formaldehyde concentrations were underpredicted in Cedar Rapids and Detroit but Seattle showed no under or overprediction.
- Applying a simple methodology for estimating secondary production of acetaldehyde and formaldehyde resulted in large overpredictions at most sites in Detroit and Seattle. For Cedar Rapids, acetaldehyde was underpredicted and formaldehyde was overpredicted using this method.
- 1,3-butadiene, benzene, and tetrachloroethylene are overpredicted in Detroit and Seattle, and underpredicted in Cedar Rapids.
- Methylene chloride is generally underpredicted, but unlike the other VOCs modeled, it is most accurately predicted in Cedar Rapids.

However, when spatial variations in concentration near monitoring sites are considered, model performance is considerably better. **Figure 5-2** provides an overview of model performance in terms of the ratio of model-predicted to observed concentrations using the best-fit (within 4.5 km) model predictions. Of the species considered risk drivers, arsenic had the poorest model performance, which did not significantly improve when the best-fit model predictions were used.

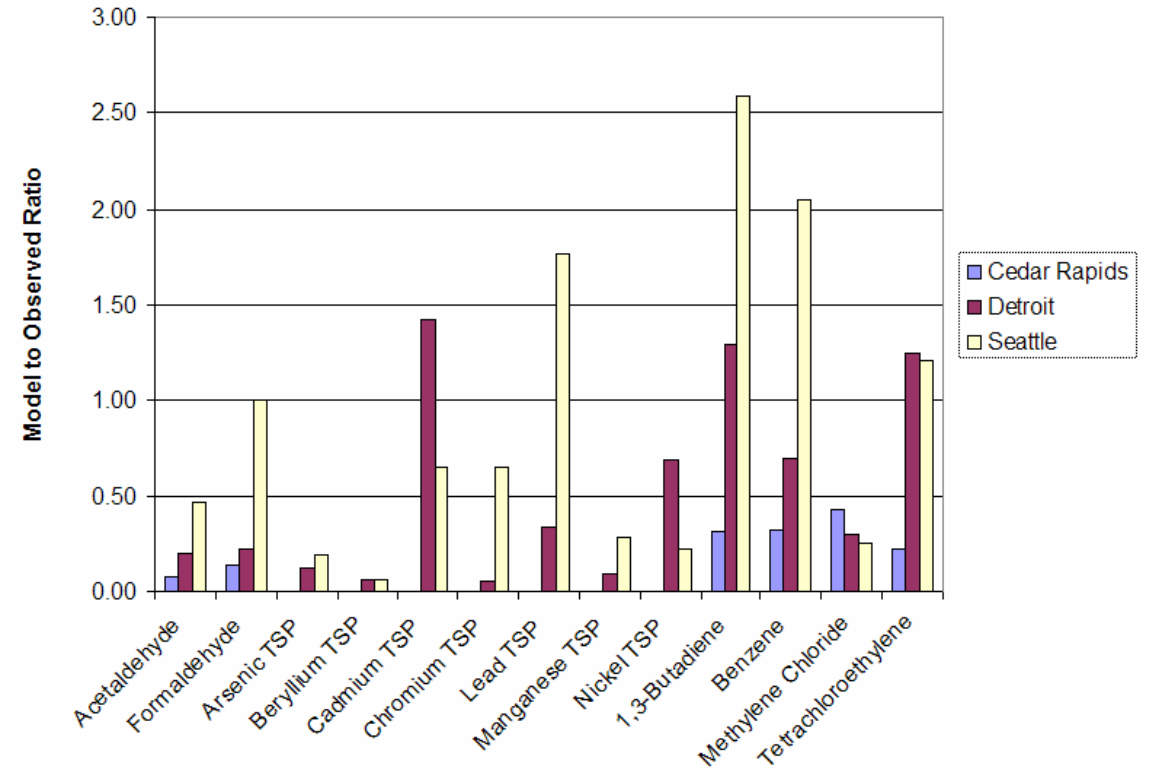

Figure 5-1. Ratios of annual average model predictions to observed HAPs concentrations.

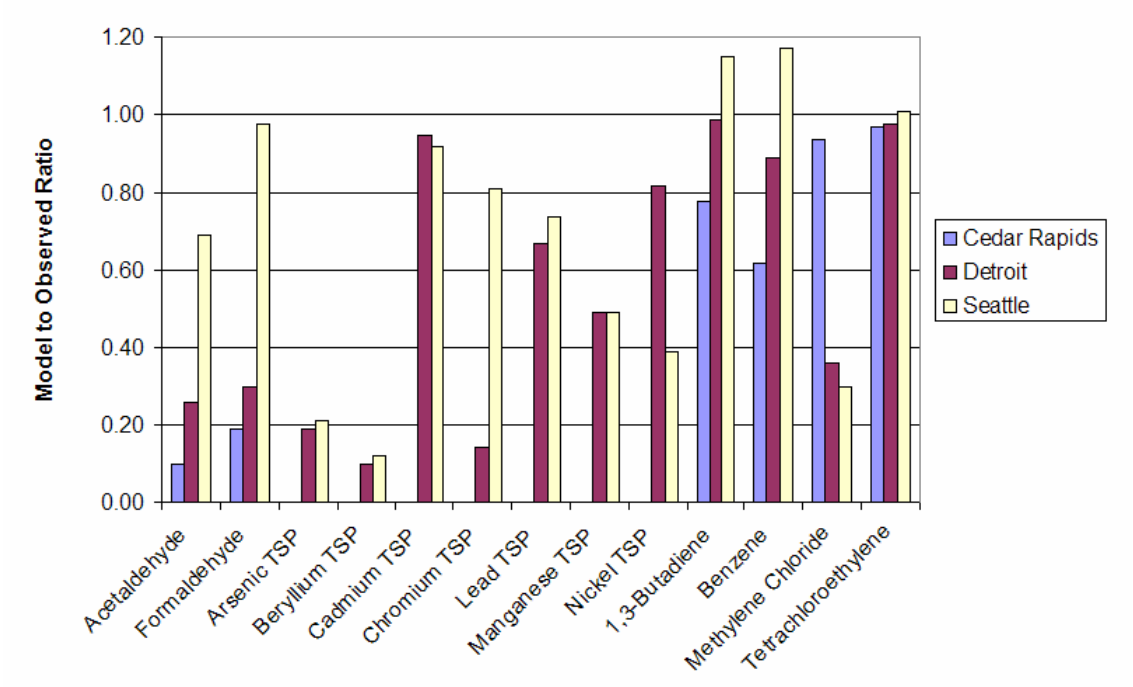

Figure 5-2. Ratios of annual average best-fit (within 4.5 km of the observation site) model predictions to observed concentrations of HAPs.

How does the performance of the current modeling compare to that done for the 1996 National Air Toxics Assessment (NATA)?

- Overall model performance for benzene was about the same as in the NATA but with a tendency to be overpredicted in the current modeling and underpredicted in the NATA. While formaldehyde and acetaldehyde were underpredictedin the NATA modeling, the use of the OZIPR model to estimate secondary formation for these species resulted in overpredictions.
- Model performance for lead, chromium, and especially cadmium was much better in the current modeling than in the NATA.

How representative are the toxics emission inventories and what is the impact of inventory quality on predicted concentrations?

- Based on best-fit model performance, the NEI appears to be of reasonable quality for the gas-phase species, except for methylene chloride. This is consistent with many of the gaseous species being dominated by mobile sources emissions, which have undergone continuous research and improvement over the past decade. The consistent underprediction of methylene chloride across all sites indicates that a significant amount of this solvent may be missing from the emissions inventory.
- Most metals were underpredicted in the current modeling study. But because model predictions for some metals (e.g., cadmium) and some low-reactivity VOCs (i.e., benzene) were not underpredicted, it is not believed that the underpredictions are a result of meteorological biases. These results infer that the emission inventory for most of the metals is underestimated. Improvements to inventories of toxic metals should focus initially on risk drivers such as arsenic.
- The overprediction of lead TSP at the SeaTac site in Seattle was found to be a result of lead emission from general aviation fuel being allocated to all airports based on their spatial size. Future modeling studies should verify that current speciation profiles for general aviation fuels are used.
- Allocation of mobile source emissions to 1-km areas for modeling was not sufficient to resolve concentration gradients near roadways. The model results indicate that it may be more difficult to model mobile sources in smaller cities where emissions are less ubiquitous, and in areas where sites are located at the upwind edge of the city, than in larger cities. Where there is a potential for significant exposure from roadways, detailed roadway inventories and line-source modeling may be more appropriate.

How can background concentrations for toxics be defined for use in near-source modeling and are there sufficient measurements to establish operational background concentrations?

- Upwind monitoring stations, chemical lifetimes, and ambient monitoring data can be used to help identify operational background concentrations on a site-by-site basis. However, few monitoring stations are always upwind of a site.
- The remote background concentrations routinely measured at NOAA CMDL monitoring stations provide reasonable estimates of global background concentrations and can provide reasonable estimates of regional background for species that currently have no

significant sources of emissions in the United States (e.g., carbon tetrachloride) or that are removed rapidly from the atmosphere (e.g., 1,3-butadiene).

What alternatives to using measurements can be used for establishing background concentrations?

- Photochemical grid models can be used to establish regional and urban-scale operational background concentrations for both reactive and non-reactive species. While photochemical grid models require considerable resources to setup, run, and evaluate, representing the secondary formation of risk drivers such as formaldehyde and acetaldehyde properly will be necessary before air quality models can become useful planning tools.

What are the impacts of complex meteorology, terrain, and emissions patterns on predicted concentrations?

- While these impacts were not explicitly investigated in this study, some information about these impacts was inferred from the differences between sites and cities.
- The gradients in modeled concentrations near monitoring sites indicate that while a model may accurately predict near-site concentrations, it may not predict the concentrations in the correct location. This may be a result of meteorological complexity (the meteorology used in the model is not representative of all locations) or emissions complexity (cases with many industrial point sources or spatial allocation of non-point sources by spatial surrogates). Failure to get concentrations in the correct locations may result in any exposure estimates being useless for planning purposes.

Should current modeling tools be used in air toxics planning?

The utility of any modeling tool depends on the location and species being modeled. Based on the model evaluation and issues noted in this study, the current approach may have some use in air toxics planning.

- For cases where species are non-reactive, emissions are well-known, and meteorology does not spatially vary significantly, the tools used in this study may be appropriate for planning purposes.
- For cases where meteorological or emissions complexity is an issue, the tools used in this study have limited applicability for planning purposes because of their inability to use varying meteorology needed to properly estimate the exposure to HAPs.
- For cases with significant contributions of HAPs from sources beyond the 50-km modeling domain, the tools used in this study are insufficient for use in air toxics planning.
- For cases where secondary formation of HAPs is being addressed, the tools used in this study may have limited usefulness. In Seattle, for example, the OZIPR estimated secondary formaldehyde and acetaldehyde concentrations alone were three and ten times the observed concentrations, respectively. Because these species are considered risk drivers, care should be taken to accurately model their secondary formation.

However, it is recommended that further investigations be performed to assess the impact of biases in the modeling system on exposure calculations While the modeling methods used in the NATA and this study have many limitations when used for assessing current exposure or predicting future exposure to HAPs, meteorological and air quality modeling tools capable of addressing those limitations are currently available. These other models may be more complex but that level of complexity will be required to predict the effect of emission controls on HAPs.

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APPENDIX A

(Available in electronic form only)

TABLES OF MONTHLY AVERAGE PREDICTIONS AND OBSERVATIONS

Table A-1. January average predicted concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	0.1963	0.2733								0.0342	0.3375	0.1579	0.0531
	Hawkeye Downs	0.1911	0.2601								0.0295	0.2994	0.1261	0.0389
	Average	0.1937	0.2667								0.0318	0.3185	0.1420	0.0460
Detroit	696_Lodge	0.3667	0.7311	0.00016	0.0000057	0.00011	0.00009	0.00195	0.00080	0.00045	0.1728	1.6546	0.2585	0.2966
	Allen Park	0.3102	0.5580	0.00014	0.0000027	0.00049	0.00008	0.00209	0.00150	0.00090	0.1256	1.3094	0.3339	0.3185
	Dearborn	0.2844	0.5001	0.00016	0.0000038	0.00022	0.00020	0.00365	0.00409	0.00143	0.1003	1.0662	0.3282	0.3770
	East 7 Mile	0.2600	0.4380	0.00021	0.0000038	0.00057	0.00027	0.00233	0.00108	0.00056				
	River Rouge	0.2360	0.3732	0.00015	0.0000027	0.00025	0.00013	0.01159	0.01328	0.00155	0.0606	0.7292	0.2931	0.3004
	South West HS	0.3026	0.5486	0.00015	0.0000031	0.00034	0.00021	0.00437	0.00374	0.00238	0.1162	1.2046	0.3037	0.3351
	Yellow Freight	0.2577	0.4309	0.00017	0.0000037	0.00032	0.00024	0.00785	0.01353	0.00193	0.0761	0.8737	0.3084	0.3368
	Ypsilanti	0.2497	0.4266	0.00017	0.0000035	0.00067	0.00012	0.00179	0.00074	0.00041	0.0766	0.8005	0.2473	0.1941
	Average	0.2834	0.5008	0.00016	0.0000036	0.00037	0.00017	0.00445	0.00485	0.00120	0.1040	1.0912	0.2961	0.3083
Seattle	Beacon Hill	0.5395	1.2264								0.1770	2.5592	0.3507	0.1450
	Georgetown	0.6784	1.6961								0.2170	2.9501	0.6214	0.1880
	Lake Forest Park	0.5559	1.3604	0.00019	0.0000002	0.00010	0.00070	0.00108	0.00114	0.00013	0.1656	2.5388	0.3926	0.1657
	Lake Sammamish	0.3812	0.7672	0.00015	0.0000001	0.00005	0.00035	0.00102	0.00093	0.00012	0.1047	1.5515	0.2102	0.0867
	Maple Leaf Reservoir	0.4201	0.7937	0.00015	0.0000001	0.00004	0.00051	0.00120	0.00098	0.00035	0.1359	1.8736	0.2606	0.0773
	Sea Tac	0.7681	1.9900	0.00019	0.0000001	0.00014	0.00096	0.02111	0.00287	0.00022	0.2472	3.0296	0.3967	0.1908
	Average	0.5572	1.3056	0.00017	0.0000001	0.00008	0.00063	0.00610	0.00148	0.00020	0.1746	2.4171	0.3720	0.1422
All	**Average**	0.3749	0.7733	0.00017	0.0000024	0.00028	0.00032	0.00500	0.00372	0.00086	0.1226	1.5185	0.3059	0.2069

Table A-2. February average predicted concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	0.1893	0.2606								0.0296	0.2993	0.1437	0.0491
	Hawkeye Downs	0.1843	0.2480								0.0251	0.2601	0.1101	0.0327
	Average	0.1868	0.2543								0.0273	0.2797	0.1269	0.0409
Detroit	696_Lodge	0.3559	0.7036	0.00015	0.0000055	0.00015	0.00009	0.00188	0.00083	0.00052	0.1627	1.5797	0.2565	0.2935
	Allen Park	0.2969	0.5345	0.00015	0.0000031	0.00052	0.00009	0.00211	0.00118	0.00060	0.1147	1.1976	0.3454	0.3220
	Dearborn	0.2815	0.4948	0.00015	0.0000040	0.00019	0.00020	0.00356	0.00557	0.00138	0.0975	1.0404	0.3381	0.3830
	East 7 Mile	0.2601	0.4457	0.00030	0.0000065	0.00084	0.00056	0.00312	0.00164	0.00074				
	River Rouge	0.2359	0.3781	0.00015	0.0000030	0.00020	0.00011	0.00851	0.00881	0.00079	0.0622	0.7135	0.2966	0.2996
	South West HS	0.2965	0.5518	0.00015	0.0000031	0.00035	0.00012	0.00345	0.00383	0.00340	0.1087	1.1250	0.3001	0.3251
	Yellow Freight	0.2552	0.4388	0.00016	0.0000035	0.00027	0.00014	0.00533	0.00656	0.00150	0.0736	0.8255	0.2996	0.3287
	Ypsilanti	0.2345	0.3916	0.00016	0.0000028	0.00042	0.00012	0.00141	0.00070	0.00028	0.0676	0.7030	0.2205	0.1583
	Average	0.2771	0.4924	0.00017	0.0000039	0.00037	0.00018	0.00367	0.00364	0.00115	0.0981	1.0264	0.2938	0.3015
Seattle	Beacon Hill	0.5737	1.2976								0.1810	2.5832	0.3699	0.1501
	Georgetown	0.7040	1.7390								0.2165	2.9014	0.7761	0.1883
	Lake Forest Park	0.5991	1.4068	0.00019	0.0000002	0.00011	0.00078	0.00178	0.00155	0.00020	0.1755	2.6802	0.3946	0.1719
	Lake Sammamish	0.4098	0.8159	0.00016	0.0000001	0.00005	0.00042	0.00144	0.00124	0.00014	0.1129	1.6748	0.2238	0.0932
	Maple Leaf Reservoir	0.4652	0.8652	0.00015	0.0000001	0.00005	0.00068	0.00247	0.00156	0.00050	0.1480	1.9999	0.2655	0.0890
	Sea Tac	0.8417	2.1569	0.00019	0.0000002	0.00013	0.00090	0.02656	0.00202	0.00025	0.2618	2.9807	0.3986	0.1916
	Average	0.5989	1.3802	0.00017	0.0000002	0.00009	0.00070	0.00806	0.00159	0.00027	0.1826	2.4700	0.4048	0.1474
All	**Average**	0.3865	0.7955	0.00017	0.0000027	0.00027	0.00035	0.00514	0.00296	0.00085	0.1225	1.5043	0.3159	0.2051

Table A-3. March average predicted concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	0.1956	0.2706								0.0323	0.3182	0.1362	0.0493
	Hawkeye Downs	0.1906	0.2576								0.0267	0.2808	0.1126	0.0310
	Average	0.1931	0.2641								0.0295	0.2995	0.1244	0.0401
Detroit	696_Lodge	0.3771	0.7753	0.00016	0.0000044	0.00012	0.00010	0.00202	0.00080	0.00061	0.1777	1.6798	0.2588	0.2946
	Allen Park	0.3261	0.5890	0.00016	0.0000033	0.00084	0.00011	0.00287	0.00142	0.00068	0.1311	1.3604	0.3856	0.3662
	Dearborn	0.3038	0.5388	0.00016	0.0000037	0.00016	0.00025	0.00229	0.00724	0.00149	0.1130	1.1804	0.3660	0.4210
	East 7 Mile	0.2769	0.4748	0.00026	0.0000054	0.00085	0.00041	0.00320	0.00201	0.00127				
	River Rouge	0.2622	0.4254	0.00015	0.0000029	0.00027	0.00014	0.00878	0.00960	0.00112	0.0763	0.8501	0.3188	0.3171
	South West HS	0.3165	0.5747	0.00015	0.0000029	0.00042	0.00016	0.00559	0.00524	0.00407	0.1234	1.2685	0.3417	0.3511
	Yellow Freight	0.2754	0.4640	0.00016	0.0000034	0.00035	0.00019	0.00896	0.02177	0.00246	0.0861	0.9741	0.3803	0.3818
	Ypsilanti	0.2399	0.3940	0.00015	0.0000018	0.00014	0.00008	0.00160	0.00074	0.00037	0.0705	0.7093	0.2248	0.1561
	Average	0.2972	0.5295	0.00017	0.0000035	0.00039	0.00018	0.00441	0.00610	0.00150	0.1112	1.1461	0.3251	0.3268
Seattle	Beacon Hill	0.5125	1.0346								0.1963	2.3894	0.3652	0.1437
	Georgetown	0.6378	1.4236								0.2448	2.6730	0.7230	0.1791
	Lake Forest Park	0.5164	1.0559	0.00017	0.0000002	0.00009	0.00066	0.00217	0.00166	0.00018	0.1927	2.4417	0.4065	0.1746
	Lake Sammamish	0.3474	0.6271	0.00015	0.0000001	0.00003	0.00024	0.00102	0.00072	0.00011	0.1088	1.3544	0.1931	0.0781
	Maple Leaf Reservoir	0.4478	0.7946	0.00014	0.0000001	0.00004	0.00064	0.00315	0.00173	0.00046	0.1640	2.0423	0.2816	0.0926
	Sea Tac	0.7513	1.7079	0.00017	0.0000002	0.00010	0.00071	0.02562	0.00209	0.00020	0.2774	2.7450	0.4028	0.1922
	Average	0.5355	1.1073	0.00016	0.0000001	0.00007	0.00056	0.00799	0.00155	0.00023	0.1973	2.2743	0.3953	0.1434
All	**Average**	0.3736	0.7130	0.00017	0.0000024	0.00028	0.00031	0.00561	0.00459	0.00108	0.1347	1.4845	0.3265	0.2152

Table A-4. April average predicted concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	0.1853	0.2513								0.0256	0.2660	0.1209	0.0404
	Hawkeye Downs	0.1824	0.2440								0.0227	0.2445	0.1115	0.0325
	Average	0.1838	0.2476								0.0241	0.2553	0.1162	0.0364
Detroit	696_Lodge	0.3883	0.7701	0.00015	0.0000046	0.00009	0.00008	0.00292	0.00154	0.00066	0.1888	1.7806	0.2659	0.2955
	Allen Park	0.3124	0.5616	0.00014	0.0000024	0.00045	0.00008	0.00178	0.00100	0.00048	0.1252	1.2814	0.3631	0.3398
	Dearborn	0.2951	0.5206	0.00015	0.0000031	0.00011	0.00018	0.00457	0.00928	0.00114	0.1088	1.1145	0.3488	0.3908
	East 7 Mile	0.2692	0.4717	0.00023	0.0000041	0.00057	0.00036	0.00244	0.00132	0.00064				
	River Rouge	0.2473	0.3969	0.00014	0.0000022	0.00017	0.00009	0.00464	0.00296	0.00067	0.0699	0.7511	0.3034	0.3014
	South West HS	0.3040	0.5647	0.00014	0.0000023	0.00032	0.00011	0.00491	0.01165	0.00354	0.1147	1.1579	0.3092	0.3185
	Yellow Freight	0.2625	0.4497	0.00015	0.0000025	0.00026	0.00013	0.01046	0.02796	0.00154	0.0779	0.8856	0.3685	0.3547
	Ypsilanti	0.2418	0.3912	0.00016	0.0000021	0.00053	0.00014	0.00161	0.00077	0.00042	0.0705	0.7042	0.2168	0.1453
	Average	0.2901	0.5158	0.00016	0.0000029	0.00031	0.00015	0.00417	0.00706	0.00113	0.1080	1.0965	0.3108	0.3066
Seattle	Beacon Hill	0.4575	0.9152								0.1696	2.0824	0.3315	0.1311
	Georgetown	0.5997	1.3533								0.2282	2.4347	0.5651	0.1686
	Lake Forest Park	0.4782	0.9983	0.00017	0.0000002	0.00007	0.00056	0.00139	0.00120	0.00015	0.1780	2.2217	0.3787	0.1634
	Lake Sammamish	0.3254	0.5854	0.00014	0.0000001	0.00003	0.00022	0.00087	0.00074	0.00010	0.0979	1.2183	0.1861	0.0736
	Maple Leaf Reservoir	0.4060	0.7230	0.00014	0.0000001	0.00003	0.00045	0.00195	0.00119	0.00031	0.1446	1.7935	0.2646	0.0850
	Sea Tac	0.6486	1.5076	0.00017	0.0000001	0.00009	0.00066	0.01982	0.00176	0.00019	0.2475	2.5236	0.3851	0.1809
	Average	0.4859	1.0138	0.00016	0.0000001	0.00006	0.00047	0.00601	0.00122	0.00018	0.1776	2.0457	0.3518	0.1338
All	**Average**	0.3502	0.6691	0.00016	0.0000020	0.00023	0.00026	0.00478	0.00511	0.00082	0.1247	1.3640	0.3013	0.2014

Table A-5. May average predicted concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	0.1937	0.2675								0.0309	0.3089	0.1416	0.0491
	Hawkeye Downs	0.1890	0.2565								0.0275	0.2756	0.1157	0.0371
	Average	0.1914	0.2620								0.0292	0.2922	0.1287	0.0431
Detroit	696_Lodge	0.4058	0.8687	0.00016	0.0000056	0.00018	0.00010	0.00251	0.00106	0.00070	0.1950	1.8579	0.2878	0.3377
	Allen Park	0.3451	0.6251	0.00016	0.0000037	0.00149	0.00011	0.00255	0.00154	0.00098	0.1452	1.5941	0.5271	0.4673
	Dearborn	0.3211	0.5729	0.00016	0.0000042	0.00015	0.00019	0.00314	0.00733	0.00140	0.1255	1.3135	0.4050	0.4701
	East 7 Mile	0.2888	0.5169	0.00022	0.0000043	0.00073	0.00028	0.00270	0.00154	0.00123				
	River Rouge	0.2770	0.4530	0.00016	0.0000034	0.00034	0.00015	0.00771	0.00626	0.00173	0.0879	0.9726	0.3644	0.3666
	South West HS	0.3350	0.6117	0.00016	0.0000035	0.00043	0.00024	0.00613	0.00695	0.00962	0.1372	1.4173	0.3820	0.3913
	Yellow Freight	0.2941	0.5024	0.00016	0.0000040	0.00042	0.00027	0.01085	0.02944	0.00560	0.0990	1.2017	0.5399	0.4916
	Ypsilanti	0.2469	0.4074								0.0745	0.7656	0.2433	0.1758
	Average	0.3142	0.5698	0.00017	0.0000041	0.00053	0.00019	0.00508	0.00773	0.00303	0.1235	1.3032	0.3928	0.3858
Seattle	Beacon Hill	0.5292	1.0446								0.1897	2.2972	0.3892	0.1458
	Georgetown	0.7304	1.6664								0.2665	2.6352	0.9721	0.1844
	Lake Forest Park	0.5393	1.0508	0.00018	0.0000004	0.00009	0.00068	0.00233	0.00167	0.00024	0.1909	2.4467	0.3980	0.1765
	Lake Sammamish	0.3658	0.6448	0.00015	0.0000001	0.00003	0.00029	0.00101	0.00077	0.00011	0.1112	1.3937	0.2056	0.0849
	Maple Leaf Reservoir	0.4869	0.8339	0.00015	0.0000001	0.00006	0.00096	0.00360	0.00189	0.00073	0.1706	2.1650	0.3029	0.1063
	Sea Tac	0.7760	1.7898	0.00018	0.0000002	0.00010	0.00072	0.02876	0.00190	0.00022	0.2839	2.7289	0.4153	0.1967
	Average	0.5713	1.1717	0.00017	0.0000002	0.00007	0.00066	0.00893	0.00156	0.00032	0.2021	2.2778	0.4472	0.1491
All	**Average**	0.3953	0.7570	0.00017	0.0000027	0.00037	0.00036	0.00648	0.00549	0.00205	0.1424	1.5583	0.3793	0.2454

Table A-6. June average predicted concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	0.2018	0.2738								0.0319	0.3552	0.1499	0.0542
	Hawkeye Downs	0.1993	0.2659								0.0296	0.3364	0.1411	0.0466
	Average	0.2005	0.2699								0.0308	0.3458	0.1455	0.0504
Detroit	696_Lodge	0.4501	0.8578	0.00016	0.0000044	0.00031	0.00014	0.00363	0.00229	0.00117	0.2146	2.3359	0.3471	0.4246
	Allen Park	0.3546	0.6047	0.00015	0.0000028	0.00093	0.00010	0.00224	0.00129	0.00103	0.1385	1.6901	0.4988	0.4846
	Dearborn	0.3309	0.5429	0.00015	0.0000034	0.00015	0.00019	0.00488	0.00788	0.00177	0.1152	1.4384	0.4500	0.5386
	East 7 Mile	0.2978	0.4850	0.00030	0.0000066	0.00090	0.00058	0.00397	0.00216	0.00097				
	River Rouge	0.2698	0.3927	0.00015	0.0000026	0.00021	0.00015	0.00586	0.00580	0.00150	0.0674	0.9886	0.3897	0.4148
	South West HS	0.3384	0.5689	0.00015	0.0000028	0.00031	0.00021	0.00815	0.01634	0.00632	0.1246	1.4984	0.4066	0.4438
	Yellow Freight	0.2873	0.4376	0.00015	0.0000032	0.00031	0.00024	0.01520	0.04376	0.00341	0.0772	1.2104	0.5639	0.5346
	Ypsilanti	0.2632	0.4038								0.0749	0.9001	0.2743	0.2133
	Average	0.3240	0.5367	0.00017	0.0000037	0.00045	0.00023	0.00628	0.01136	0.00231	0.1161	1.4374	0.4186	0.4363
Seattle	Beacon Hill	0.4187	0.6978								0.1517	2.0965	0.3515	0.1457
	Georgetown	0.5907	1.2103								0.2290	2.4423	0.6545	0.1818
	Lake Forest Park	0.4307	0.7542	0.00016	0.0000002	0.00006	0.00046	0.00179	0.00120	0.00015	0.1773	2.2551	0.4056	0.1835
	Lake Sammamish	0.3217	0.4918	0.00014	0.0000001	0.00002	0.00023	0.00104	0.00072	0.00011	0.0940	1.2870	0.1988	0.0860
	Maple Leaf Reservoir	0.3792	0.5877	0.00014	0.0000001	0.00003	0.00052	0.00257	0.00123	0.00040	0.1287	1.8977	0.2925	0.0989
	Sea Tac	0.6202	1.2697	0.00016	0.0000001	0.00007	0.00053	0.02009	0.00175	0.00017	0.2431	2.5397	0.4037	0.2004
	Average	0.4602	0.8352	0.00015	0.0000001	0.00005	0.00044	0.00637	0.00123	0.00020	0.1706	2.0864	0.3844	0.1494
All	**Average**	0.3597	0.6153	0.00016	0.0000024	0.00030	0.00030	0.00631	0.00767	0.00154	0.1265	1.5515	0.3685	0.2701

Table A-7. July average predicted concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	0.2065	0.2799								0.0340	0.3827	0.1569	0.0581
	Hawkeye Downs	0.2025	0.2692								0.0298	0.3554	0.1298	0.0469
	Average	0.2045	0.2745								0.0319	0.3691	0.1434	0.0525
Detroit	696_Lodge	0.4359	0.8265	0.00017	0.0000047	0.00049	0.00015	0.00287	0.00121	0.00125	0.2081	2.2295	0.3492	0.4280
	Allen Park	0.3572	0.6083	0.00015	0.0000031	0.00072	0.00013	0.00267	0.00158	0.00095	0.1395	1.6825	0.4686	0.4808
	Dearborn	0.3372	0.5515	0.00016	0.0000038	0.00032	0.00027	0.00446	0.00831	0.00141	0.1180	1.5109	0.4642	0.5626
	East 7 Mile	0.3126	0.4999	0.00029	0.0000066	0.00137	0.00054	0.00509	0.00392	0.00191				
	River Rouge	0.2835	0.4144	0.00015	0.0000028	0.00031	0.00019	0.00769	0.01033	0.00173	0.0738	1.0956	0.4038	0.4284
	South West HS	0.3476	0.5792	0.00015	0.0000030	0.00053	0.00025	0.00917	0.01069	0.00531	0.1276	1.5962	0.4455	0.4802
	Yellow Freight	0.2993	0.4550	0.00016	0.0000035	0.00046	0.00028	0.01613	0.04242	0.00256	0.0827	1.2868	0.5633	0.5524
	Ypsilanti	0.2494	0.3862								0.0699	0.8300	0.2569	0.1876
	Average	0.3278	0.5401	0.00018	0.0000039	0.00060	0.00026	0.00687	0.01121	0.00216	0.1171	1.4616	0.4216	0.4457
Seattle	Beacon Hill	0.4189	0.7069								0.1529	2.1035	0.3557	0.1455
	Georgetown	0.6702	1.4586								0.2588	2.4937	0.6575	0.1869
	Lake Forest Park	0.4300	0.7588	0.00017	0.0000003	0.00007	0.00049	0.00169	0.00152	0.00018	0.1770	2.2614	0.3883	0.1849
	Lake Sammamish	0.3123	0.4969	0.00014	0.0000001	0.00002	0.00020	0.00078	0.00074	0.00009	0.0953	1.2633	0.1943	0.0848
	Maple Leaf Reservoir	0.3837	0.6068	0.00014	0.0000001	0.00004	0.00053	0.00217	0.00152	0.00036	0.1343	1.9658	0.2852	0.1010
	Sea Tac	0.6674	1.3453	0.00016	0.0000001	0.00007	0.00051	0.02163	0.00113	0.00018	0.2551	2.6243	0.4165	0.2108
	Average	0.4804	0.8955	0.00015	0.0000001	0.00005	0.00043	0.00657	0.00123	0.00020	0.1789	2.1187	0.3829	0.1523
All	**Average**	0.3696	0.6402	0.00017	0.0000026	0.00040	0.00032	0.00676	0.00758	0.00144	0.1304	1.5788	0.3690	0.2759

Table A-8. August average predicted concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	0.2120	0.2907								0.0375	0.4137	0.1730	0.0617
	Hawkeye Downs	0.2075	0.2776								0.0333	0.3841	0.1480	0.0518
	Average	0.2098	0.2842								0.0354	0.3989	0.1605	0.0568
Detroit	696_Lodge	0.4337	0.8349	0.00016	0.0000042	0.00023	0.00014	0.00270	0.00123	0.00092	0.2092	2.1871	0.3310	0.4095
	Allen Park	0.3525	0.6056	0.00015	0.0000028	0.00083	0.00011	0.00287	0.00168	0.00080	0.1380	1.6433	0.4785	0.4743
	Dearborn	0.3319	0.5502	0.00016	0.0000037	0.00028	0.00027	0.00517	0.00949	0.00213	0.1164	1.4299	0.4471	0.5410
	East 7 Mile	0.3022	0.4931	0.00026	0.0000054	0.00114	0.00044	0.00405	0.00242	0.00155				
	River Rouge	0.2773	0.4100	0.00015	0.0000026	0.00029	0.00014	0.00959	0.01329	0.00143	0.0721	1.0185	0.3802	0.4073
	South West HS	0.3448	0.5841	0.00015	0.0000028	0.00049	0.00019	0.00699	0.00755	0.00712	0.1286	1.5348	0.4147	0.4571
	Yellow Freight	0.2940	0.4530	0.00016	0.0000032	0.00043	0.00022	0.01536	0.03787	0.00316	0.0815	1.1465	0.4297	0.4747
	Ypsilanti	0.2593	0.4065								0.0755	0.8815	0.2733	0.2070
	Average	0.3245	0.5422	0.00017	0.0000035	0.00053	0.00022	0.00668	0.01050	0.00244	0.1173	1.4059	0.3935	0.4244
Seattle	Beacon Hill	0.4496	0.7564								0.1688	2.2955	0.3762	0.1559
	Georgetown	0.6620	1.3883								0.2604	2.6638	0.7987	0.1992
	Lake Forest Park	0.4611	0.8134	0.00016	0.0000002	0.00007	0.00051	0.00158	0.00119	0.00018	0.1936	2.4392	0.4256	0.1994
	Lake Sammamish	0.3265	0.5218	0.00014	0.0000001	0.00003	0.00023	0.00096	0.00082	0.00011	0.1029	1.3951	0.2147	0.0940
	Maple Leaf Reservoir	0.4069	0.6340	0.00014	0.0000001	0.00003	0.00062	0.00232	0.00131	0.00050	0.1440	2.0761	0.2943	0.1019
	Sea Tac	0.6792	1.4326	0.00016	0.0000001	0.00009	0.00061	0.02432	0.00205	0.00021	0.2747	2.8090	0.4459	0.2216
	Average	0.4976	0.9244	0.00015	0.0000001	0.00006	0.00049	0.00730	0.00134	0.00025	0.1907	2.2798	0.4259	0.1620
All	**Average**	0.3750	0.6533	0.00016	0.0000023	0.00036	0.00032	0.00690	0.00717	0.00164	0.1357	1.6212	0.3754	0.2704

Table A-9. September average predicted concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	0.2022	0.2767								0.0338	0.3692	0.1610	0.0606
	Hawkeye Downs	0.1962	0.2623								0.0277	0.3237	0.1240	0.0411
	Average	0.1992	0.2695								0.0308	0.3465	0.1425	0.0509
Detroit	696_Lodge	0.4510	0.8765	0.00016	0.0000065	0.00042	0.00011	0.00300	0.00137	0.00102	0.2156	2.3314	0.3497	0.4475
	Allen Park	0.3638	0.6181	0.00015	0.0000037	0.00123	0.00009	0.00231	0.00114	0.00066	0.1431	1.8422	0.5170	0.5231
	Dearborn	0.3369	0.5561	0.00016	0.0000047	0.00015	0.00020	0.00506	0.00839	0.00142	0.1196	1.5621	0.4649	0.5743
	East 7 Mile	0.3034	0.4937	0.00033	0.0000080	0.00151	0.00065	0.00482	0.00283	0.00119				
	River Rouge	0.2794	0.4054	0.00015	0.0000038	0.00025	0.00016	0.00715	0.00433	0.00174	0.0714	1.1303	0.4181	0.4635
	South West HS	0.3486	0.5860	0.00015	0.0000039	0.00038	0.00019	0.00934	0.01047	0.00593	0.1288	1.6531	0.4354	0.4806
	Yellow Freight	0.2987	0.4564	0.00016	0.0000044	0.00032	0.00022	0.01909	0.03917	0.00391	0.0831	1.2582	0.4291	0.4917
	Ypsilanti	0.2517	0.3977	0.00017	0.0000029	0.00056	0.00014	0.00207	0.00076	0.00031	0.0723	0.8609	0.2642	0.2060
	Average	0.3292	0.5487	0.00018	0.0000047	0.00060	0.00022	0.00661	0.00856	0.00202	0.1191	1.5198	0.4112	0.4552
Seattle	Beacon Hill	0.5832	1.0256								0.1955	2.9740	0.4768	0.1907
	Georgetown	0.8590	1.8886								0.3001	3.3474	1.1109	0.2498
	Lake Forest Park	0.5855	1.0998	0.00019	0.0000003	0.00013	0.00096	0.00286	0.00253	0.00034	0.2095	3.1403	0.4963	0.2375
	Lake Sammamish	0.3869	0.6707	0.00015	0.0000001	0.00005	0.00037	0.00115	0.00111	0.00014	0.1217	1.8347	0.2498	0.1152
	Maple Leaf Reservoir	0.5080	0.7712	0.00015	0.0000002	0.00008	0.00111	0.00417	0.00300	0.00080	0.1668	2.6864	0.3507	0.1295
	Sea Tac	0.9449	2.0709	0.00019	0.0000004	0.00014	0.00096	0.03757	0.00266	0.00028	0.3281	3.5375	0.5213	0.2667
	Average	0.6446	1.2544	0.00017	0.0000002	0.00010	0.00085	0.01144	0.00233	0.00039	0.2203	2.9200	0.5343	0.1982
All	**Average**	0.4312	0.7785	0.00018	0.0000032	0.00044	0.00043	0.00822	0.00648	0.00147	0.1478	1.9234	0.4246	0.2985

Table A-10. October average predicted concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	0.1977	0.2702								0.0315	0.3439	0.1592	0.0541
	Hawkeye Downs	0.1933	0.2579								0.0277	0.3159	0.1346	0.0453
	Average	0.1955	0.2640								0.0296	0.3299	0.1469	0.0497
Detroit	696_Lodge	0.3904	0.7506	0.00016	0.0000047	0.00023	0.00012	0.00239	0.00083	0.00060	0.1773	1.8623	0.2831	0.3365
	Allen Park	0.3196	0.5493	0.00015	0.0000027	0.00081	0.00008	0.00208	0.00137	0.00063	0.1211	1.4309	0.4155	0.3921
	Dearborn	0.2937	0.4880	0.00015	0.0000031	0.00013	0.00015	0.00292	0.00484	0.00152	0.0979	1.1735	0.3668	0.4337
	East 7 Mile	0.2659	0.4341	0.00021	0.0000033	0.00075	0.00024	0.00224	0.00119	0.00089				
	River Rouge	0.2438	0.3595	0.00015	0.0000024	0.00024	0.00011	0.00882	0.00626	0.00149	0.0567	0.7970	0.3208	0.3346
	South West HS	0.3069	0.5277	0.00015	0.0000025	0.00033	0.00018	0.00537	0.00934	0.00537	0.1096	1.2644	0.3378	0.3657
	Yellow Freight	0.2623	0.4112	0.00015	0.0000029	0.00032	0.00021	0.00984	0.03427	0.00253	0.0692	0.9417	0.3661	0.3871
	Ypsilanti	0.2475	0.3844	0.00015	0.0000019	0.00077	0.00011	0.00227	0.00073	0.00031	0.0669	0.7986	0.2503	0.1938
	Average	0.2913	0.4881	0.00016	0.0000029	0.00045	0.00015	0.00449	0.00735	0.00166	0.0998	1.1812	0.3343	0.3491
Seattle	Beacon Hill	0.4964	0.8939								0.1702	2.4870	0.4019	0.1620
	Georgetown	0.6400	1.3332								0.2241	2.7528	0.8864	0.2154
	Lake Forest Park	0.4986	0.9378	0.00017	0.0000003	0.00009	0.00069	0.00211	0.00196	0.00028	0.1755	2.5397	0.4160	0.1902
	Lake Sammamish	0.3543	0.5777	0.00015	0.0000001	0.00004	0.00032	0.00137	0.00088	0.00014	0.1021	1.6110	0.2310	0.0994
	Maple Leaf Reservoir	0.4313	0.6710	0.00014	0.0000001	0.00005	0.00081	0.00257	0.00223	0.00066	0.1409	2.1373	0.2875	0.1036
	Sea Tac	0.7923	1.7184	0.00018	0.0000002	0.00010	0.00070	0.02999	0.00193	0.00028	0.2696	2.8717	0.4306	0.2237
	Average	0.5355	1.0220	0.00016	0.0000002	0.00007	0.00063	0.00901	0.00175	0.00034	0.1804	2.3999	0.4422	0.1657
All	**Average**	0.3709	0.6603	0.00016	0.0000020	0.00032	0.00031	0.00600	0.00549	0.00122	0.1227	1.5552	0.3525	0.2358

Table A-11. November average predicted concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	0.1984	0.2732								0.0317	0.3449	0.1445	0.0524
	Hawkeye Downs	0.1948	0.2622								0.0292	0.3231	0.1299	0.0482
	Average	0.1966	0.2677								0.0304	0.3340	0.1372	0.0503
Detroit	696_Lodge	0.4269	0.8376	0.00015	0.0000053	0.00011	0.00009	0.00241	0.00083	0.00059	0.2039	2.1489	0.3066	0.3975
	Allen Park	0.3695	0.6327	0.00015	0.0000031	0.00100	0.00010	0.00251	0.00152	0.00114	0.1490	1.8614	0.4703	0.4735
	Dearborn	0.3349	0.5600	0.00016	0.0000039	0.00019	0.00022	0.00354	0.00571	0.00154	0.1209	1.5218	0.4151	0.5125
	East 7 Mile	0.2896	0.4805	0.00027	0.0000055	0.00068	0.00043	0.00282	0.00127	0.00064				
	River Rouge	0.2826	0.4215	0.00015	0.0000031	0.00042	0.00016	0.01187	0.00927	0.00229	0.0773	1.1523	0.3829	0.4419
	South West HS	0.3519	0.6064	0.00016	0.0000034	0.00057	0.00028	0.00453	0.00576	0.00563	0.1372	1.6466	0.3706	0.4451
	Yellow Freight	0.3046	0.4810	0.00017	0.0000040	0.00050	0.00031	0.00709	0.01239	0.00313	0.0935	1.2918	0.3840	0.4668
	Ypsilanti	0.2544	0.4016	0.00016	0.0000024	0.00119	0.00011	0.00172	0.00074	0.00035	0.0728	0.8876	0.2696	0.2210
	Average	0.3268	0.5527	0.00017	0.0000038	0.00058	0.00021	0.00456	0.00469	0.00191	0.1221	1.5014	0.3713	0.4226
Seattle	Beacon Hill	0.5158	0.9522								0.1903	2.9000	0.4104	0.1775
	Georgetown	0.6665	1.4168								0.2525	3.3319	0.6803	0.2427
	Lake Forest Park	0.5174	1.0524	0.00018	0.0000001	0.00010	0.00070	0.00161	0.00127	0.00015	0.1992	2.8228	0.4762	0.2171
	Lake Sammamish	0.3507	0.6013	0.00015	0.0000000	0.00004	0.00029	0.00098	0.00078	0.00012	0.1073	1.6525	0.2325	0.1028
	Maple Leaf Reservoir	0.4191	0.6831	0.00014	0.0000001	0.00004	0.00048	0.00227	0.00115	0.00035	0.1458	2.2353	0.3075	0.0979
	Sea Tac	0.7664	1.6803	0.00019	0.0000002	0.00012	0.00089	0.02445	0.00225	0.00028	0.2830	3.4559	0.4938	0.2502
	Average	0.5393	1.0643	0.00017	0.0000001	0.00008	0.00059	0.00733	0.00136	0.00022	0.1963	2.7331	0.4334	0.1814
All	**Average**	0.3902	0.7089	0.00017	0.0000026	0.00041	0.00034	0.00548	0.00358	0.00135	0.1396	1.8384	0.3649	0.2765

Table A-12. December average predicted concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	0.1894	0.2573								0.0279	0.3071	0.1331	0.0481
	Hawkeye Downs	0.1843	0.2441								0.0239	0.2725	0.1122	0.0370
	Average	0.1869	0.2507								0.0259	0.2898	0.1227	0.0426
Detroit	696_Lodge	0.4087	0.7943	0.00016	0.0000078	0.00023	0.00012	0.00257	0.00094	0.00070	0.1926	2.0485	0.3056	0.3787
	Allen Park	0.3383	0.5901	0.00016	0.0000043	0.00075	0.00011	0.00285	0.00148	0.00097	0.1325	1.6062	0.4234	0.4212
	Dearborn	0.3126	0.5266	0.00016	0.0000054	0.00027	0.00026	0.00408	0.00771	0.00174	0.1078	1.4092	0.4143	0.4987
	East 7 Mile	0.2803	0.4542	0.00024	0.0000056	0.00054	0.00032	0.00273	0.00121	0.00079				
	River Rouge	0.2588	0.3847	0.00015	0.0000042	0.00038	0.00015	0.01092	0.00985	0.00225	0.0634	0.9992	0.3733	0.3966
	South West HS	0.3312	0.5748	0.00016	0.0000044	0.00060	0.00025	0.00377	0.00373	0.00334	0.1248	1.5244	0.3713	0.4259
	Yellow Freight	0.2806	0.4426	0.00016	0.0000050	0.00057	0.00028	0.00622	0.00853	0.00199	0.0788	1.1911	0.4399	0.4718
	Ypsilanti	0.2527	0.4055	0.00017	0.0000040	0.00086	0.00014	0.00194	0.00072	0.00035	0.0723	0.8982	0.2715	0.2142
	Average	0.3079	0.5216	0.00017	0.0000051	0.00053	0.00020	0.00439	0.00427	0.00151	0.1103	1.3824	0.3713	0.4010
Seattle	Beacon Hill	0.4990	1.0466								0.1455	2.4507	0.3367	0.1445
	Georgetown	0.6188	1.4602								0.1783	2.8350	0.5626	0.1810
	Lake Forest Park	0.5329	1.2483	0.00018	0.0000002	0.00010	0.00072	0.00126	0.00136	0.00016	0.1516	2.5566	0.3810	0.1641
	Lake Sammamish	0.3706	0.6792	0.00016	0.0000001	0.00005	0.00038	0.00117	0.00089	0.00013	0.0917	1.6673	0.2251	0.0946
	Maple Leaf Reservoir	0.3895	0.6514	0.00015	0.0000001	0.00004	0.00046	0.00149	0.00130	0.00032	0.1142	1.8270	0.2499	0.0807
	Sea Tac	0.7339	1.7808	0.00019	0.0000001	0.00014	0.00090	0.02153	0.00262	0.00024	0.2130	2.9121	0.3907	0.1828
	Average	0.5241	1.1444	0.00017	0.0000001	0.00008	0.00062	0.00636	0.00154	0.00021	0.1490	2.3748	0.3577	0.1413
All	**Average**	0.3738	0.7213	0.00017	0.0000034	0.00038	0.00034	0.00504	0.00336	0.00108	0.1145	1.6337	0.3327	0.2493

Table A-13. January average observed concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	Formaldehyde	Arsenic TSP	Beryllium TSP	Cadmium TSP	Chromium TSP	Lead TSP	Manganese TSP	Nickel TSP	1,3-Butadiene	Benzene	Methylene Chloride	Tetrachloroethylene
Cedar Rapids	Army Reserve	1.7077	1.2691								0.0872	0.9323	0.1429	0.2034
	Hawkeye Downs	1.5818	1.5111								0.0843	0.9311	0.4615	0.2034
	Average	1.6448	1.3901								0.0857	0.9317	0.3022	0.2034
Detroit	696_Lodge	0.8476	1.0183	0.00028	0.0000499	0.00003	0.00176	0.00208	0.00234	0.00079	0.2211	2.3152	1.3021	0.3051
	Allen Park	1.2413	1.5637	0.00104	0.0000499	0.00038	0.00304	0.00929	0.01898	0.00153	0.0774	1.4530	47.6733	0.5085
	Dearborn	1.1727	1.8760	0.00231	0.0001311	0.00058	0.00761	0.03450	0.36349	0.00180	0.1022	1.6206	5.8178	0.3052
	East 7 Mile	1.3907	2.3815	0.00112	0.0000497	0.00058	0.00244	0.01241	0.02924	0.00160				
	River Rouge	1.3858	2.5312	0.00135	0.0000498	0.00044	0.00349	0.01624	0.04160	0.00116	0.1520	1.8648	108.8416	0.9847
	South West HS	1.2984	1.9619	0.00158	0.0000684	0.00126	0.00437	0.01791	0.07032	0.00160	0.0442	0.9207	0.7144	0.2407
	Yellow Freight	0.6131	1.7383	0.00296	0.0001944	0.00171	0.00680	0.02668	0.14123	0.00305	0.1813	11.8602	2.0694	0.2441
	Ypsilanti	1.0283	1.3130	0.00083	0.0000499	0.00026	0.00202	0.00717	0.00792	0.00055	0.0442	0.8327	0.7893	0.2407
	Average	1.1223	1.7980	0.00143	0.0000804	0.00066	0.00394	0.01579	0.08439	0.00151	0.1175	2.9810	23.8869	0.4041
Seattle	Beacon Hill	0.8068	0.8938								0.0341	0.6368	1.7490	0.0868
	Georgetown	1.0265	1.1970								0.0923	1.2965	2.0299	0.2915
	Lake Forest Park	0.8392	0.6777	0.00147	0.0000015	0.00013	0.00052	0.00321	0.00409	0.00063	0.1161	1.7532	1.8653	0.1681
	Lake Sammamish	0.8824	0.4272	0.00053	0.0000015	0.00021	0.00042	0.00228	0.00338	0.00030	0.0232	0.7428	1.6979	0.0712
	Maple Leaf Reservoir	0.8896	0.7514	0.00083	0.0000015	0.00007	0.00040	0.00358	0.00280	0.00047	0.0296	0.7530	1.9773	0.1085
	Sea Tac	1.0193	0.8422	0.00068	0.0000015	0.00009	0.00047	0.00256	0.00274	0.00049	0.0232	0.6968	1.6300	0.0854
	Average	0.9107	0.7982	0.00088	0.0000015	0.00012	0.00045	0.00291	0.00325	0.00047	0.0531	0.9798	1.8249	0.1353
All	**Average**	1.1082	1.3721	0.00125	0.0000541	0.00048	0.00278	0.01149	0.05735	0.00116	0.0875	1.9073	11.9174	0.2698

Table A-14. February average observed concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	Formaldehyde	Arsenic TSP	Beryllium TSP	Cadmium TSP	Chromium TSP	Lead TSP	Manganese TSP	Nickel TSP	1,3-Butadiene	Benzene	Methylene Chloride	Tetrachloroethylene
Cedar Rapids	Army Reserve	1.5125	0.9821								0.0862	1.1539	0.1391	0.2034
	Hawkeye Downs	3.7706	1.4484								0.0852	1.1546	0.1781	0.2034
	Average	2.6416	1.2152								0.0857	1.1543	0.1586	0.2034
Detroit	696_Lodge	1.3398	1.8764	0.00111	0.0000458	0.00025	0.00450	0.00731	0.02044	0.00171	0.1437	2.0246	5.4097	0.2983
	Allen Park	1.0956	1.6080	0.00094	0.0000478	0.00036	0.00332	0.00805	0.02463	0.00153	0.1161	1.9160	484.0767	0.2034
	Dearborn	1.3477	2.2227	0.00278	0.0001658	0.00044	0.00675	0.02666	0.23702	0.00190	0.0833	1.4859	27.1154	0.3373
	East 7 Mile	1.0184	1.8996	0.00212	0.0000499	0.00033	0.00319	0.01157	0.02892	0.00126				
	River Rouge	1.5281	3.2903	0.00147	0.0000508	0.00155	0.00749	0.01962	0.13486	0.00147	0.0608	1.5194	8.3803	0.9171
	South West HS	1.3831	2.2467	0.00159	0.0001034	0.00088	0.00571	0.01728	0.10348	0.00183	0.0442	4.6145	12.2251	0.2407
	Yellow Freight	1.1515	1.4372	0.00247	0.0003238	0.00136	0.00846	0.02932	0.23544	0.00408	0.1592	39.7128	4.3541	0.2034
	Ypsilanti	0.8110	1.5224	0.00067	0.0000498	0.00016	0.00225	0.00431	0.00860	0.00072	0.0442	1.0679	0.3993	0.2407
	Average	1.2094	2.0129	0.00164	0.0001046	0.00067	0.00521	0.01551	0.09918	0.00181	0.0931	7.4773	77.4229	0.3487
Seattle	Beacon Hill	0.8392	1.1074								0.0287	0.7862	2.8893	0.1139
	Georgetown	1.3002	1.5224								0.1203	1.9697	2.2168	0.4461
	Lake Forest Park	1.0355	1.0221	0.00176	0.0000023	0.00016	0.00150	0.00641	0.00707	0.00101	0.0462	1.4108	1.7455	0.7281
	Lake Sammamish	1.3957	0.8410	0.00073	0.0000055	0.00021	0.00124	0.00390	0.00897	0.00081	0.0232	0.6594	1.6512	0.0610
	Maple Leaf Reservoir	1.0553	1.1246	0.00098	0.0000015	0.00012	0.00103	0.00400	0.00532	0.00101	0.0407	0.7996	2.0137	0.1736
	Sea Tac	1.2210	1.2670	0.00108	0.0000032	0.00014	0.00186	0.00516	0.00927	0.00133	0.0398	0.8941	1.9481	0.1234
	Average	1.1412	1.1474	0.00114	0.0000031	0.00016	0.00141	0.00487	0.00766	0.00104	0.0498	1.0867	2.0774	0.2743
All	**Average**	1.3628	1.5886	0.00148	0.0000708	0.00050	0.00394	0.01196	0.06867	0.00156	0.0748	4.0780	36.9828	0.2996

Table A-15. March average observed concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	Formaldehyde	Arsenic TSP	Beryllium TSP	Cadmium TSP	Chromium TSP	Lead TSP	Manganese TSP	Nickel TSP	1,3-Butadiene	Benzene	Methylene Chloride	Tetrachloroethylene
Cedar Rapids	Army Reserve	1.4452	1.0683								0.0932	0.9520	0.1165	0.2034
	Hawkeye Downs	2.2045	1.7512								0.1026	1.0988	0.3530	0.2034
	Average	1.8248	1.4098								0.0979	1.0254	0.2348	0.2034
Detroit	696_Lodge	1.0565	1.5366	0.00111	0.0000497	0.00023	0.00358	0.00644	0.01511	0.00221	0.0774	1.5520	30.6040	0.2034
	Allen Park	1.0201	1.4812	0.00081	0.0000437	0.00063	0.00296	0.00767	0.02136	0.00189	0.1493	1.5328	2265.6796	0.2034
	Dearborn	1.2376	2.1535	0.00209	0.0002317	0.00085	0.00778	0.01887	0.22517	0.00236	0.0844	1.4957	37.6439	0.2783
	East 7 Mile	1.3979	2.7719	0.00083	0.0000972	0.00027	0.00284	0.00725	0.02182	0.00129				
	River Rouge	1.3435	9.0366	0.00103	0.0000497	0.00033	0.00591	0.01362	0.07399	0.00149	0.1050	1.5566	1.2735	0.2127
	South West HS	0.9581	1.6071	0.00142	0.0000692	0.00099	0.00648	0.01941	0.08864	0.00316	0.0442	0.9899	3.2639	0.2373
	Yellow Freight	1.1386	1.9882	0.00272	0.0004012	0.00166	0.00786	0.02636	0.18801	0.00287	0.1172	16.9824	2.8750	0.2034
	Ypsilanti	0.7096	1.3732	0.00064	0.0000497	0.00015	0.00207	0.00548	0.00758	0.00106	0.0442	0.6800	0.3993	0.2407
	Average	1.1077	2.7436	0.00133	0.0001240	0.00064	0.00494	0.01314	0.08021	0.00204	0.0888	3.5413	334.5342	0.2256
Seattle	Beacon Hill	0.7204	1.2032								0.0685	1.0994	1.3414	0.1207
	Georgetown	0.9365	1.5224								0.1006	1.4611	1.7693	0.2576
	Lake Forest Park	1.0805	1.1541	0.00127	0.0000035	0.00033	0.00133	0.00346	0.00602	0.00125	0.1276	1.7296	1.8621	0.1393
	Lake Sammamish	0.9004	0.9085	0.00039	0.0000061	0.00005	0.00091	0.00214	0.00614	0.00125	0.0707	1.2261	1.6466	0.1243
	Maple Leaf Reservoir	1.0085	1.1541	0.00073	0.0000045	0.00008	0.00119	0.00343	0.00695	0.00134	0.0717	1.3059	1.7702	0.5402
	Sea Tac	1.0085	1.4242	0.00069	0.0000063	0.00010	0.00155	0.00283	0.00503	0.00173	0.2329	1.4755	1.3909	0.2863
	Average	0.9425	1.2277	0.00077	0.0000051	0.00014	0.00125	0.00296	0.00603	0.00139	0.1120	1.3829	1.6301	0.2447
All	**Average**	1.1354	2.0084	0.00114	0.0000844	0.00047	0.00371	0.00975	0.05548	0.00182	0.0993	2.3425	156.7993	0.2303

Table A-16. April average observed concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	Formaldehyde	Arsenic TSP	Beryllium TSP	Cadmium TSP	Chromium TSP	Lead TSP	Manganese TSP	Nickel TSP	1,3-Butadiene	Benzene	Methylene Chloride	Tetrachloroethylene
Cedar Rapids	Army Reserve	1.5479	1.5072								0.0866	0.7751	0.2561	0.2034
	Hawkeye Downs	3.3307	2.2911								0.0965	0.8580	0.4931	0.2034
	Average	2.4393	1.8991								0.0916	0.8165	0.3746	0.2034
Detroit	696_Lodge	1.5489	1.8911	0.00146	0.0000498	0.00028	0.00361	0.00771	0.01972	0.00151	0.1548	1.7244	169.6169	0.2034
	Allen Park	1.3074	1.5225	0.00149	0.0000498	0.00041	0.00324	0.01010	0.02839	0.00197	0.0774	1.2986	500.5060	0.5198
	Dearborn	1.1880	3.6014	0.00158	0.0000840	0.00090	0.00471	0.02245	0.08864	0.00223	0.0979	1.7085	12.2375	1.0349
	East 7 Mile	0.8876	1.4093	0.00169	0.0000506	0.00028	0.00244	0.01012	0.01922	0.00196				
	River Rouge	1.6646	3.3484	0.00189	0.0003148	0.00065	0.00371	0.01319	0.04996	0.00166	0.0774	1.8681	0.3299	0.2034
	South West HS	1.5029	2.2811	0.00215	0.0002692	0.00253	0.00439	0.02211	0.07601	0.00364	0.0442	6.8658	2.4305	0.2373
	Yellow Freight	1.4919	2.5634	0.00202	0.0001372	0.00065	0.00515	0.01945	0.09999	0.00262	0.1437	20.5653	1.0208	0.2034
	Ypsilanti	1.2129	2.2117	0.00059	0.0000498	0.00016	0.00290	0.00398	0.02293	0.00109	0.0442	0.9899	0.3993	0.2373
	Average	1.3505	2.3536	0.00161	0.0001256	0.00073	0.00377	0.01364	0.05061	0.00209	0.0914	5.0030	98.0773	0.3771
Seattle	Beacon Hill	1.3507	2.2099								0.0535	1.0726	1.1830	0.0949
	Georgetown	0.9725	1.3750								0.0678	1.1252	1.6749	0.3878
	Lake Forest Park	1.2246	1.3505	0.00166	0.0000087	0.00012	0.00113	0.00503	0.00643	0.00163	0.0414	1.4513	1.9458	0.1966
	Lake Sammamish	1.0805	1.0558	0.00074	0.0000048	0.00012	0.00079	0.00299	0.00677	0.00125	0.0885	1.3846	1.7524	0.0874
	Maple Leaf Reservoir	1.0805	1.5960	0.00085	0.0000089	0.00010	0.00095	0.00462	0.00695	0.00160	0.0679	1.1651	1.9244	0.1578
	Sea Tac	0.9725	1.4978	0.00073	0.0000077	0.00014	0.00191	0.00411	0.01186	0.00220	0.0621	1.1206	1.3972	0.0856
	Average	1.1136	1.5142	0.00099	0.0000075	0.00012	0.00120	0.00419	0.00800	0.00167	0.0635	1.2199	1.6463	0.1684
All	**Average**	1.3978	1.9820	0.00140	0.0000863	0.00053	0.00291	0.01049	0.03641	0.00195	0.0803	2.9315	46.4779	0.2704

Table A-17. May average observed concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	Formaldehyde	Arsenic TSP	Beryllium TSP	Cadmium TSP	Chromium TSP	Lead TSP	Manganese TSP	Nickel TSP	1,3-Butadiene	Benzene	Methylene Chloride	Tetrachloroethylene
Cedar Rapids	Army Reserve	1.9007	2.4198								0.0874	0.7014	0.4859	0.2034
	Hawkeye Downs	3.5217	3.8021								0.1696	1.5216	0.1993	0.2568
	Average	2.7112	3.1110								0.1285	1.1115	0.3426	0.2301
Detroit	696_Lodge	2.0436	3.2951	0.00161	0.0000400	0.00024	0.00341	0.00782	0.01995	0.00208	0.1794	2.0771	0.5065	0.3367
	Allen Park	2.4319	3.1627	0.00259	0.0000500	0.00039	0.00335	0.01028	0.03088	0.00249	0.1182	1.2454	5.8737	0.4024
	Dearborn	2.5029	4.0655	0.00234	0.0001008	0.00063	0.00470	0.02363	0.11076	0.00314	0.1360	2.1648	0.8633	0.4012
	East 7 Mile	2.1581	2.9649	0.00231	0.0000611	0.00040	0.00302	0.01225	0.03228	0.00307				
	River Rouge	4.6327	9.3796	0.00232	0.0000616	0.00087	0.00664	0.04177	0.11421	0.00412	0.1732	2.5622	0.5339	0.3977
	South West HS	4.6377	7.5346	0.00282	0.0000996	0.00079	0.00588	0.02885	0.08621	0.00545	0.0442	1.4045	0.8240	0.2407
	Yellow Freight	2.6359	3.8988	0.00326	0.0006798	0.00097	0.00877	0.03684	0.49263	0.00667	0.2448	47.0294	0.5256	0.4040
	Ypsilanti	0.7474	1.0620								0.0442	1.4071	0.5580	0.3430
	Average	2.7238	4.4204	0.00246	0.0001561	0.00061	0.00511	0.02307	0.12670	0.00386	0.1343	8.2701	1.3836	0.3608
Seattle	Beacon Hill	1.3507	2.3122								0.1001	1.3258	1.4528	0.2576
	Georgetown	1.0505	1.6370								0.1069	1.2923	1.7558	0.3390
	Lake Forest Park	1.4707	1.6779	0.00116	0.0000027	0.00017	0.00089	0.00399	0.00494	0.00122	0.0881	1.6032	2.3762	0.1743
	Lake Sammamish	1.2906	1.5960	0.00085	0.0000037	0.00018	0.00072	0.00268	0.00594	0.00102	0.0966	1.4224	1.8328	0.1328
	Maple Leaf Reservoir	1.3207	1.9030	0.00089	0.0000037	0.00017	0.00092	0.00355	0.00541	0.00157	0.0474	1.3013	2.7643	0.1765
	Sea Tac	1.8609	2.0053	0.00121	0.0000055	0.00016	0.00282	0.00571	0.01084	0.00262	0.0747	1.2269	1.9692	0.1552
	Average	1.3907	1.8552	0.00103	0.0000039	0.00017	0.00134	0.00398	0.00678	0.00161	0.0856	1.3620	2.0252	0.2059
All	**Average**	2.2223	3.2948	0.00194	0.0001008	0.00045	0.00374	0.01613	0.08310	0.00304	0.1140	4.5524	1.5014	0.2814

Table A-18. June average observed concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	Formaldehyde	Arsenic TSP	Beryllium TSP	Cadmium TSP	Chromium TSP	Lead TSP	Manganese TSP	Nickel TSP	1,3-Butadiene	Benzene	Methylene Chloride	Tetrachloroethylene
Cedar Rapids	Army Reserve	5.6222	4.0051								0.0933	0.9350	0.4429	0.2034
	Hawkeye Downs	3.2686	4.1071								0.1353	1.1656	0.4294	0.3073
	Average	4.4454	4.0561								0.1143	1.0503	0.4362	0.2553
Detroit	696_Lodge	2.2293	4.0503	0.00187	0.0000400	0.00021	0.00331	0.00868	0.01412	0.00457	0.1776	1.9387	76.5519	0.3253
	Allen Park	2.4280	3.9305	0.00359	0.0000543	0.00060	0.00345	0.01282	0.02873	0.00308	0.0774	1.2186	1565.4678	0.3559
	Dearborn	1.9165	3.1295	0.00310	0.0001006	0.00084	0.00577	0.02066	0.13510	0.00490	0.1007	2.1237	3.3102	0.5147
	East 7 Mile	2.5627	4.0556	0.00235	0.0000561	0.00037	0.00307	0.01929	0.03737	0.00378				
	River Rouge	2.8568	7.9507	0.00315	0.0000560	0.00069	0.00522	0.02543	0.07344	0.00290	0.0575	2.3474	0.8343	0.2258
	South West HS	2.3418	5.6774	0.00307	0.0001057	0.00063	0.00743	0.03163	0.13942	0.00519	0.0442	3.7578	1.5284	0.2407
	Yellow Freight	2.8506	5.5081	0.00414	0.0002923	0.00066	0.00870	0.02842	0.24765	0.00419	0.1864	64.1972	1.0631	0.2034
	Ypsilanti	0.6123	1.8755								0.0442	1.3564	0.6583	0.3941
	Average	2.2248	4.5222	0.00304	0.0001007	0.00057	0.00528	0.02099	0.09655	0.00409	0.0983	10.9914	235.6306	0.3228
Seattle	Beacon Hill	1.2246	1.6206								0.0758	1.0521	1.3869	0.0976
	Georgetown	0.8554	1.1663								0.0535	0.8367	1.8160	0.2061
	Lake Forest Park	1.0085	1.0558	0.00066	0.0000015	0.00006	0.00081	0.00261	0.00380	0.00107	0.0712	1.0219	2.5434	0.1348
	Lake Sammamish	0.9004	0.9822	0.00055	0.0000023	0.00010	0.00071	0.00214	0.00625	0.00083	0.0493	1.1049	1.9138	0.0918
	Maple Leaf Reservoir	1.0085	1.3259	0.00044	0.0000015	0.00007	0.00110	0.00274	0.00520	0.00130	0.0491	0.9452	2.4245	0.1318
	Sea Tac	1.4407	1.2523	0.00064	0.0000017	0.00008	0.00153	0.00344	0.00707	0.00150	0.0803	0.9133	2.5207	0.1005
	Average	1.0730	1.2339	0.00057	0.0000017	0.00008	0.00104	0.00273	0.00558	0.00118	0.0632	0.9790	2.1009	0.1271
All	**Average**	2.0704	3.2308	0.00214	0.0000647	0.00039	0.00374	0.01435	0.06347	0.00303	0.0864	5.6610	110.8594	0.2355

Table A-19. July average observed concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	Formaldehyde	Arsenic TSP	Beryllium TSP	Cadmium TSP	Chromium TSP	Lead TSP	Manganese TSP	Nickel TSP	1,3-Butadiene	Benzene	Methylene Chloride	Tetrachloroethylene
Cedar Rapids	Army Reserve	3.4605	4.9550								0.0835	0.9314	0.5105	0.2034
	Hawkeye Downs	1.9872	3.4403								0.0857	0.9032	0.7332	0.2034
	Average	2.7239	4.1976								0.0846	0.9173	0.6218	0.2034
Detroit	696_Lodge	2.1834	3.7240	0.00112	0.0004273	0.00017	0.00207	0.00901	0.01830	0.00139	0.2268	2.5651	134.2884	0.3887
	Allen Park	2.1646	3.5079	0.00137	0.0003910	0.00038	0.00239	0.01124	0.03877	0.00204	0.0774	1.0779	5844.5546	0.3243
	Dearborn	2.3160	3.5643	0.00220	0.0000713	0.00042	0.00423	0.02316	0.13294	0.00383	0.0693	2.0461	39.4036	0.3313
	East 7 Mile	2.2032	3.6007	0.00079	0.0002210	0.00025	0.00129	0.01111	0.02337	0.00168				
	River Rouge	2.6464	10.6744	0.00187	0.0000479	0.00027	0.00437	0.01833	0.09003	0.00268	0.0641	1.7689	13.7168	0.2183
	South West HS	2.9157	6.8900	0.00192	0.0006558	0.00077	0.00451	0.02858	0.10262	0.00442	0.0442	2.1905	7.3750	0.4048
	Yellow Freight	2.2793	3.8420	0.01074	0.0005378	0.00110	0.00753	0.03854	0.48776	0.00513	0.2154	16.2864	2.2300	0.3381
	Ypsilanti	1.4632	6.5259								0.0442	0.9921	0.3993	0.2407
	Average	2.2715	5.2911	0.00286	0.0003360	0.00048	0.00377	0.02000	0.12768	0.00302	0.1059	3.8467	863.1382	0.3209
Seattle	Beacon Hill	1.4767	2.3327								0.0529	1.1362	1.9522	0.0407
	Georgetown	1.0445	1.6451								0.0535	0.9836	1.8539	0.1542
	Lake Forest Park	1.3327	1.3259	0.00056	0.0000015	0.00003	0.00064	0.00389	0.00495	0.00126	0.0758	0.9580	2.4419	0.0407
	Lake Sammamish	1.4767	1.4978	0.00061	0.0000049	0.00005	0.00118	0.00341	0.00968	0.00121	0.0363	1.1496	1.9086	0.0793
	Maple Leaf Reservoir	1.3057	1.7188	0.00042	0.0000024	0.00003	0.00086	0.00401	0.00708	0.00150	0.0537	1.2263	2.4556	0.0614
	Sea Tac	1.6208	1.7188	0.00047	0.0000056	0.00005	0.00166	0.00325	0.01022	0.00199	0.0714	0.8111	2.5754	0.0407
	Average	1.3762	1.7065	0.00051	0.0000036	0.00004	0.00108	0.00364	0.00798	0.00149	0.0573	1.0441	2.1979	0.0695
All	**Average**	1.9923	3.8102	0.00201	0.0002151	0.00032	0.00279	0.01405	0.08416	0.00247	0.0836	2.3351	403.7599	0.2047

Table A-20. August average observed concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	Formaldehyde	Arsenic TSP	Beryllium TSP	Cadmium TSP	Chromium TSP	Lead TSP	Manganese TSP	Nickel TSP	1,3-Butadiene	Benzene	Methylene Chloride	Tetrachloroethylene
Cedar Rapids	Army Reserve	2.7723	4.1390								0.0835	0.9300	0.2352	0.2034
	Hawkeye Downs	2.9397	3.2533								0.0949	0.9609	0.2548	0.2034
	Average	2.8560	3.6961								0.0892	0.9455	0.2450	0.2034
Detroit	696_Lodge	1.9413	3.2241	0.00141	0.0000495	0.00019	0.00538	0.00810	0.02120	0.02114	0.2207	2.3000	341.1837	0.4109
	Allen Park	1.8766	2.9024	0.00283	0.0000498	0.00046	0.00420	0.01175	0.04051	0.00300	0.1489	2.2241	91.2346	0.3373
	Dearborn	4.3367	4.6752	0.00205	0.0000981	0.00057	0.00640	0.02217	0.16875	0.00415	0.0943	2.2541	1.7839	0.5367
	East 7 Mile	2.2789	3.2814	0.00189	0.0000530	0.00047	0.00351	0.01251	0.02780	0.00315				
	River Rouge	2.4516	7.5472	0.00246	0.0000575	0.00119	0.00517	0.02863	0.07084	0.00440	0.0894	2.9646	2.9666	0.2258
	South West HS	2.9325	4.9858	0.00246	0.0001274	0.00091	0.00587	0.02460	0.10858	0.00598	0.0442	2.0913	2.6801	0.2407
	Yellow Freight	2.0658	4.5658	0.00268	0.0004450	0.00158	0.00958	0.04267	0.36434	0.00683	0.2212	10.6914	1.2247	0.6299
	Ypsilanti	1.2720	3.0787								0.0442	2.1089	0.6991	1.5049
	Average	2.3944	4.2826	0.00226	0.0001258	0.00077	0.00573	0.02149	0.11457	0.00695	0.1233	3.5192	63.1104	0.5552
Seattle	Beacon Hill	1.4407	2.3081								0.0916	0.9729	1.5504	0.0690
	Georgetown	1.0805	1.6697								0.0916	1.5134	1.9620	0.1056
	Lake Forest Park	1.3687	1.5224	0.00072	0.0000017	0.00007	0.00113	0.00435	0.00636	0.00155	0.0929	1.7557	1.7844	0.1403
	Lake Sammamish	1.3957	1.2891	0.00045	0.0000035	0.00005	0.00118	0.00355	0.01026	0.00138	0.1207	1.1226	1.8078	0.0991
	Maple Leaf Reservoir	1.2966	1.6206	0.00053	0.0000024	0.00007	0.00120	0.00495	0.00782	0.00172	0.0818	1.1347	1.8954	0.0625
	Sea Tac	1.6208	1.7925	0.00072	0.0000035	0.00010	0.00212	0.00761	0.01110	0.00237	0.1382	1.1728	1.6580	0.0501
	Average	1.3672	1.7004	0.00060	0.0000028	0.00007	0.00141	0.00512	0.00888	0.00175	0.1028	1.2787	1.7763	0.0878
All	**Average**	2.0669	3.2409	0.00166	0.0000810	0.00051	0.00416	0.01554	0.07614	0.00506	0.1105	2.2798	30.1947	0.3213

Table A-21. September average observed concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	**Formaldehyde**	**Arsenic TSP**	**Beryllium TSP**	**Cadmium TSP**	**Chromium TSP**	**Lead TSP**	**Manganese TSP**	**Nickel TSP**	**1,3-Butadiene**	**Benzene**	**Methylene Chloride**	**Tetrachloroethylene**
Cedar Rapids	Army Reserve	2.5692	2.8622								0.0850	1.1085	3.1030	0.2530
	Hawkeye Downs	4.2344	2.0274								0.1016	1.1253	0.3333	0.2034
	Average	3.4018	2.4448								0.0933	1.1169	1.7182	0.2282
Detroit	696_Lodge	1.3645	1.9479	0.00217	0.0000500	0.00020	0.00418	0.00820	0.01402	0.00157	0.1782	1.6111	0.2295	0.2034
	Allen Park	1.5508	1.9901	0.00418	0.0000517	0.00031	0.00451	0.01652	0.04185	0.00252	0.1856	1.6827	60.4722	0.6473
	Dearborn	3.3057	3.7207	0.00327	0.0000660	0.00049	0.00571	0.01737	0.13490	0.00318	0.1590	1.8924	2.6390	0.3622
	East 7 Mile	1.6302	2.5785	0.00184	0.0000507	0.00023	0.00325	0.00997	0.02526	0.00216				
	River Rouge	2.1575	5.5923	0.00382	0.0000632	0.00083	0.00464	0.01809	0.07317	0.00200	0.1970	2.6214	0.7158	0.2127
	South West HS	1.8423	3.5346	0.00265	0.0000765	0.00040	0.01226	0.01710	0.09695	0.00274	0.0442	4.2532	9.2470	1.2999
	Yellow Freight	1.7873	3.6313	0.00330	0.0001904	0.00091	0.00790	0.02275	0.19731	0.00334	0.1815	3.7911	0.6338	0.2034
	Ypsilanti	0.9689	1.7974	0.00069	0.0000500	0.00012	0.00252	0.00475	0.00732	0.00079	0.0442	0.5037	0.3993	0.9347
	Average	1.8259	3.0991	0.00274	0.0000748	0.00044	0.00562	0.01434	0.07385	0.00229	0.1414	2.3365	10.6195	0.5519
Seattle	Beacon Hill	1.4875	1.9103								0.0676	1.3393	1.4310	0.1005
	Georgetown	1.4659	1.3849								0.0904	2.4915	1.9302	0.1765
	Lake Forest Park	1.1166	0.8299	0.00176	0.0000026	0.00019	0.00073	0.00707	0.00433	0.00139	0.1522	2.6478	1.4168	0.0807
	Lake Sammamish	2.3484	1.0337	0.00136	0.0000036	0.00008	0.00052	0.00395	0.00598	0.00084	0.1043	1.5472	1.6992	0.1243
	Maple Leaf Reservoir	1.1796	1.0374	0.00077	0.0000023	0.00010	0.00062	0.00607	0.00499	0.00178	0.1008	1.7121	1.7614	0.0890
	Sea Tac	1.6172	1.3579	0.00115	0.0000046	0.00016	0.00301	0.00625	0.00966	0.00361	0.1059	1.1918	1.6005	0.1229
	Average	1.5359	1.2590	0.00126	0.0000033	0.00013	0.00122	0.00584	0.00624	0.00191	0.1036	1.8216	1.6398	0.1156
All	**Average**	1.9141	2.3273	0.00225	0.0000510	0.00034	0.00415	0.01151	0.05131	0.00216	0.1198	1.9679	5.8408	0.3343

Table A-22. October average observed concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	Formaldehyde	Arsenic TSP	Beryllium TSP	Cadmium TSP	Chromium TSP	Lead TSP	Manganese TSP	Nickel TSP	1,3-Butadiene	Benzene	Methylene Chloride	Tetrachloroethylene
Cedar Rapids	Army Reserve	3.4679	2.0262								0.0815	0.8024	0.3160	0.2034
	Hawkeye Downs	2.0961	1.5394								0.1129	0.8837	0.5196	0.2034
	Average	2.7820	1.7828								0.0972	0.8430	0.4178	0.2034
Detroit	696_Lodge	1.4832	2.5421	0.00159	0.0000461	0.00022	0.00413	0.00690	0.02251	0.00178	0.1371	1.4372	0.1476	0.2034
	Allen Park	1.7542	1.9255	0.00228	0.0000500	0.00038	0.00334	0.21011	0.02439	0.00173	0.1104	1.2708	39.1633	1.0459
	Dearborn	1.8881	2.8605	0.00181	0.0000828	0.00042	0.00492	0.01791	0.11987	0.00231	0.1393	1.7287	1.6850	0.4429
	East 7 Mile	1.9515	2.8657	0.00183	0.0000542	0.00025	0.00251	0.00963	0.02427	0.00177				
	River Rouge	1.7694	3.8045	0.00148	0.0000495	0.00037	0.00483	0.01205	0.08320	0.00168	0.1519	2.3785	0.4925	0.2258
	South West HS	1.7241	2.8888	0.00211	0.0000619	0.00054	0.00469	0.01939	0.09634	0.00209	0.0442	1.7712	1.5423	0.2407
	Yellow Freight	1.7161	2.8497	0.00258	0.0002533	0.00091	0.00781	0.03004	0.26651	0.00343	0.1973	39.7839	0.6253	0.2588
	Ypsilanti	0.9887	1.2678	0.00077	0.0000500	0.00012	0.00219	0.00373	0.00861	0.00073	0.0442	0.9667	0.3993	0.2407
	Average	1.6594	2.6256	0.00181	0.0000810	0.00040	0.00430	0.03872	0.08071	0.00194	0.1178	7.0481	6.2936	0.3797
Seattle	Beacon Hill	0.6483	0.7857								0.0689	1.1078	1.3396	0.1111
	Georgetown	0.8176	0.6446								0.1353	1.4254	1.7733	0.3565
	Lake Forest Park	0.7744	0.3570	0.00339	0.0000015	0.00021	0.00068	0.00816	0.00408	0.00067	0.2204	1.4258	1.2255	0.2294
	Lake Sammamish	0.7672	0.2425	0.00221	0.0000038	0.00013	0.00103	0.00446	0.00864	0.00089	0.0932	0.9479	1.7160	0.2075
	Maple Leaf Reservoir	0.6708	0.3888	0.00140	0.0000015	0.00020	0.00079	0.00517	0.00523	0.00113	0.1633	0.7438	1.7006	0.1675
	Sea Tac	0.9004	0.6507	0.00141	0.0000022	0.00023	0.00128	0.00539	0.00662	0.00129	0.1730	0.8079	1.2495	0.2373
	Average	0.7631	0.5115	0.00210	0.0000023	0.00019	0.00095	0.00579	0.00614	0.00099	0.1423	1.0764	1.5007	0.2182
All	**Average**	1.4636	1.7275	0.00191	0.0000547	0.00033	0.00318	0.02775	0.05586	0.00163	0.1249	3.8321	3.5930	0.2916

Table A-23. November average observed concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	Formaldehyde	Arsenic TSP	Beryllium TSP	Cadmium TSP	Chromium TSP	Lead TSP	Manganese TSP	Nickel TSP	1,3-Butadiene	Benzene	Methylene Chloride	Tetrachloroethylene
Cedar Rapids	Army Reserve	3.0700	1.5540								0.0979	1.1385	1.5675	0.2034
	Hawkeye Downs	10.3729	1.7593								0.2676	2.2991	0.3018	0.2034
	Average	6.7214	1.6566								0.1827	1.7188	0.9346	0.2034
Detroit	696_Lodge	1.9937	2.4433	0.00093	0.0000499	0.00021	0.00325	0.00585	0.01405	0.00143	0.2413	2.1454	0.5831	0.4475
	Allen Park	1.4846	1.6256	0.00164	0.0000499	0.00039	0.00385	0.01212	0.03622	0.00204	0.1422	1.6897	747.4254	0.2034
	Dearborn	1.7824	2.6970	0.00443	0.0001577	0.00077	0.00561	0.03788	0.31237	0.00318	0.1340	2.0300	5.3246	0.3789
	East 7 Mile	2.0249	3.0485	0.00223	0.0000495	0.00055	0.00326	0.01347	0.03416	0.00213				
	River Rouge	1.6478	3.1055	0.00186	0.0000578	0.00045	0.00482	0.01769	0.06214	0.00263	0.1942	2.3250	0.7053	0.7119
	South West HS	1.4389	2.5168	0.00219	0.0000816	0.00101	0.00571	0.01854	0.07187	0.00286	0.0442	1.0338	1.0097	0.2407
	Yellow Freight	1.6413	2.7795	0.00334	0.0004331	0.00142	0.00748	0.02900	0.28846	0.00366	0.1744	6.4152	12.8526	0.2034
	Ypsilanti	1.2786	1.5132	0.00069	0.0000499	0.00016	0.00223	0.00561	0.01069	0.00075	0.0442	1.2313	0.3993	0.2407
	Average	1.6615	2.4662	0.00216	0.0001162	0.00062	0.00453	0.01752	0.10375	0.00233	0.1392	2.4101	109.7572	0.3466
Seattle	Beacon Hill	1.6568	2.1853								0.1846	2.0922	0.9578	0.2945
	Georgetown	2.3015	1.9030								0.1304	1.7315	1.9461	0.5624
	Lake Forest Park	1.4335	0.9650	0.00249	0.0000035	0.00034	0.00137	0.00821	0.00459	0.00102	0.2934	1.7457	1.0598	0.6026
	Lake Sammamish	1.3759	0.5402	0.00100	0.0000063	0.00011	0.00080	0.00404	0.00565	0.00055	0.2412	1.3152	1.5559	0.3588
	Maple Leaf Reservoir	2.0530	1.2707	0.00117	0.0000015	0.00021	0.00083	0.00528	0.00516	0.00128	0.1241	1.2138	1.5984	0.5567
	Sea Tac	1.9017	1.4634	0.00180	0.0000041	0.00024	0.00158	0.00760	0.00644	0.00206	0.1096	1.1198	1.1360	0.2337
	Average	1.7871	1.3879	0.00162	0.0000038	0.00022	0.00115	0.00628	0.00546	0.00123	0.1806	1.5364	1.3757	0.4348
All	**Average**	2.3411	1.9606	0.00198	0.0000787	0.00049	0.00340	0.01377	0.07098	0.00197	0.1616	1.9684	51.8949	0.3628

Table A-24. December average observed concentrations in µg/m^3.

City	Station	Species												
		Acetaldehyde	Formaldehyde	Arsenic TSP	Beryllium TSP	Cadmium TSP	Chromium TSP	Lead TSP	Manganese TSP	Nickel TSP	1,3-Butadiene	Benzene	Methylene Chloride	Tetrachloroethylene
Cedar Rapids	Army Reserve	1.9623	1.2482								0.0926	0.8812	3.2417	0.2034
	Hawkeye Downs	1.5827	1.2821								0.0829	1.2037	3.5697	0.2034
	Average	1.7725	1.2652								0.0878	1.0425	3.4057	0.2034
Detroit	696_Lodge	1.3052	1.8332	0.00015	0.0000498	0.00005	0.00254	0.00142	0.00279	0.00054	0.1935	1.9820	0.7377	0.2034
	Allen Park	1.2008	1.5166	0.00133	0.0000498	0.00038	0.00355	0.01040	0.02684	0.00169	0.1522	1.5428	279.6086	0.4399
	Dearborn	1.3916	2.4562	0.00307	0.0001740	0.00073	0.00764	0.03141	0.38975	0.00287	0.1082	1.9716	7.2710	0.4753
	East 7 Mile	1.6747	2.8031	0.00199	0.0000478	0.00034	0.00295	0.01047	0.02077	0.00165				
	River Rouge	1.4113	2.9588	0.00149	0.0000498	0.00040	0.00457	0.01501	0.05785	0.00164	0.1165	2.3811	0.6779	3.5243
	South West HS	1.4515	2.3681	0.00159	0.0000662	0.00069	0.00506	0.01451	0.06885	0.00245	0.0442	2.0703	1.0324	0.2407
	Yellow Freight	1.4538	2.3241	0.00228	0.0002731	0.00104	0.00583	0.01845	0.17887	0.00250	0.1758	3.8112	1.3342	0.2034
	Ypsilanti	0.9053	1.3116	0.00113	0.0000498	0.00020	0.00206	0.00673	0.00772	0.00114	0.0442	1.5467	0.6256	0.3465
	Average	1.3493	2.1965	0.00163	0.0000951	0.00048	0.00428	0.01355	0.09418	0.00181	0.1192	2.1865	41.6125	0.7762
Seattle	Beacon Hill	2.9535	1.9152								0.0854	1.5909	0.7231	0.3394
	Georgetown	1.4911	1.4585								0.1296	1.1838	1.5200	0.7900
	Lake Forest Park	1.4119	0.9011	0.00256	0.0000018	0.00012	0.00059	0.00430	0.00337	0.00042	0.1090	1.2691	0.7689	0.2405
	Lake Sammamish	1.6172	1.9202	0.00073	0.0000043	0.00009	0.00082	0.00318	0.00539	0.00070	0.0934	0.8689	1.5071	0.3986
	Maple Leaf Reservoir	0.8149	0.4993	0.00096	0.0000015	0.00008	0.00051	0.00389	0.00372	0.00093	0.0774	0.9967	1.2725	0.2389
	Sea Tac	1.0949	0.7784	0.00104	0.0000018	0.00011	0.00074	0.00372	0.00364	0.00077	0.0566	0.8179	1.0699	0.1774
	Average	1.5639	1.2455	0.00132	0.0000023	0.00010	0.00066	0.00377	0.00403	0.00070	0.0919	1.1212	1.1436	0.3641
All	**Average**	1.4827	1.7234	0.00153	0.0000642	0.00036	0.00307	0.01029	0.06413	0.00144	0.1041	1.6079	20.3307	0.5350

APPENDIX B

(Available in electronic form only)

PLOTS OF MONTHLY VARIATIONS IN MODEL PERFORMANCE

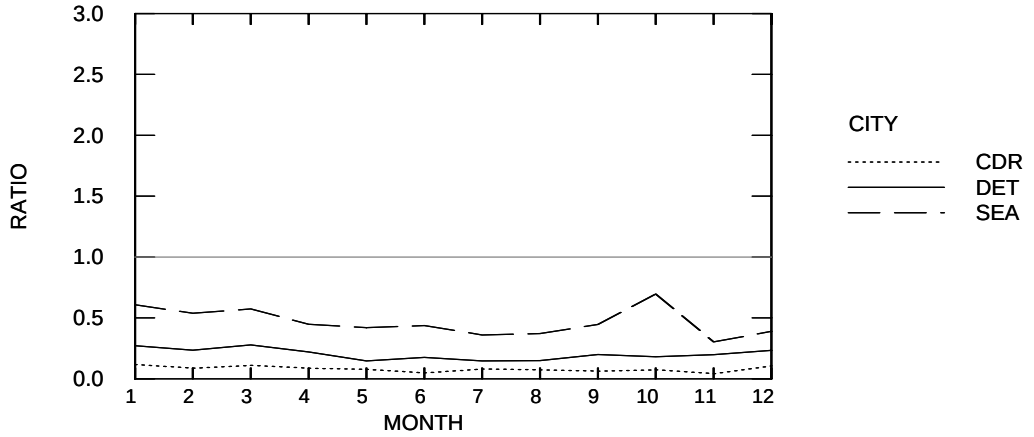

Figure B-1. Monthly average prediction to observed concentration ratios for acetaldehyde.

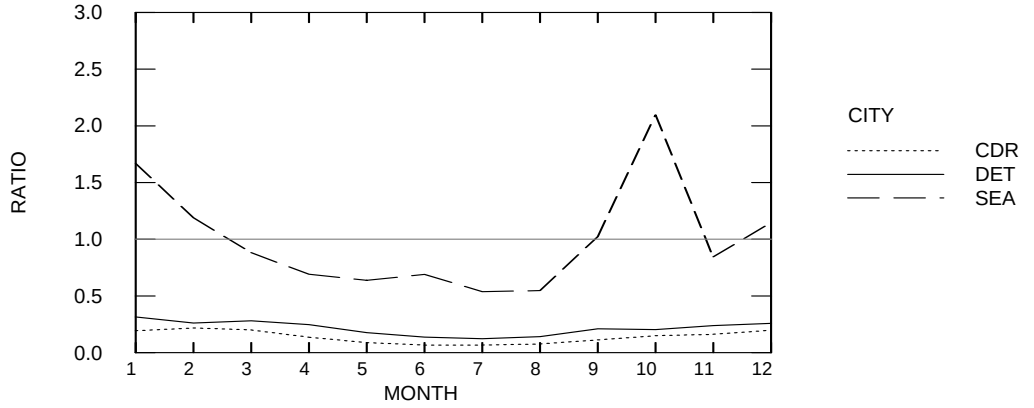

Figure B-2. Monthly average prediction to observed concentration ratios for formaldehyde.

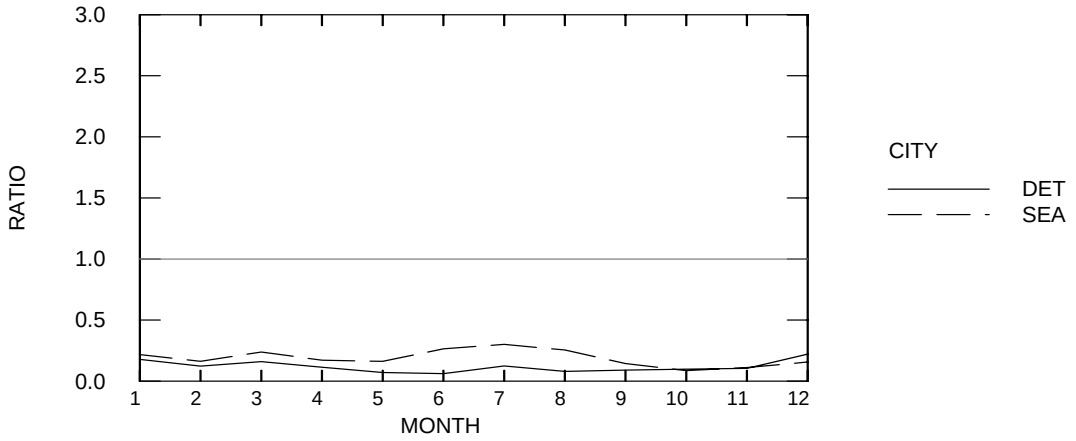

Figure B-3. Monthly average prediction to observed concentration ratios for arsenic TSP.

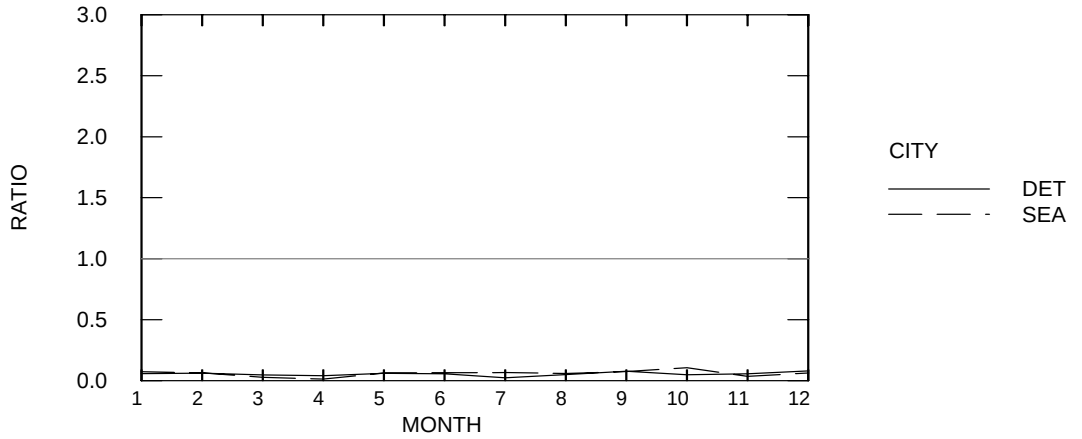

Figure B-4. Monthly average prediction to observed concentration ratios for beryllium TSP.

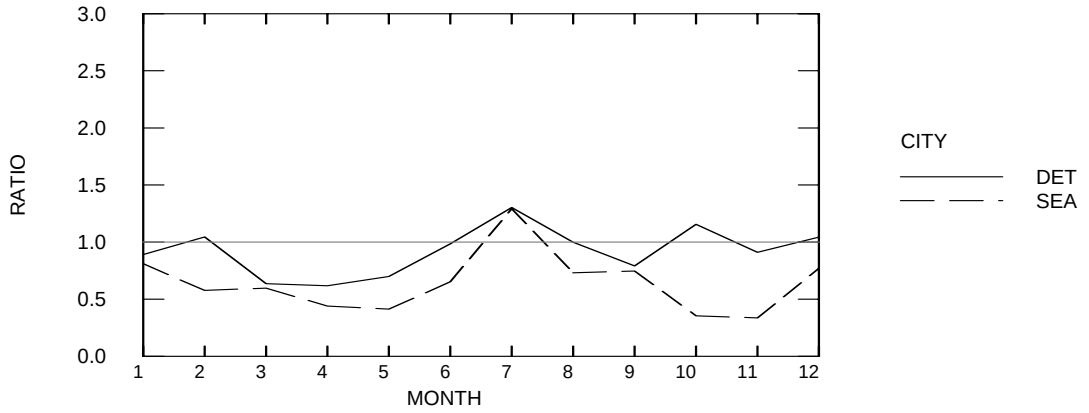

Figure B-5. Monthly average prediction to observed concentration ratios for cadmium TSP.

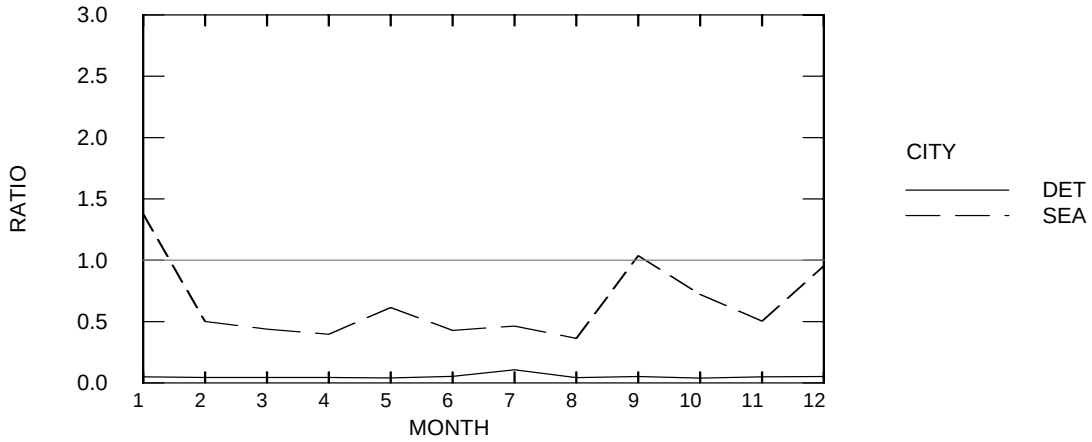

Figure B-6. Monthly average prediction to observed concentration ratios for chromium TSP.

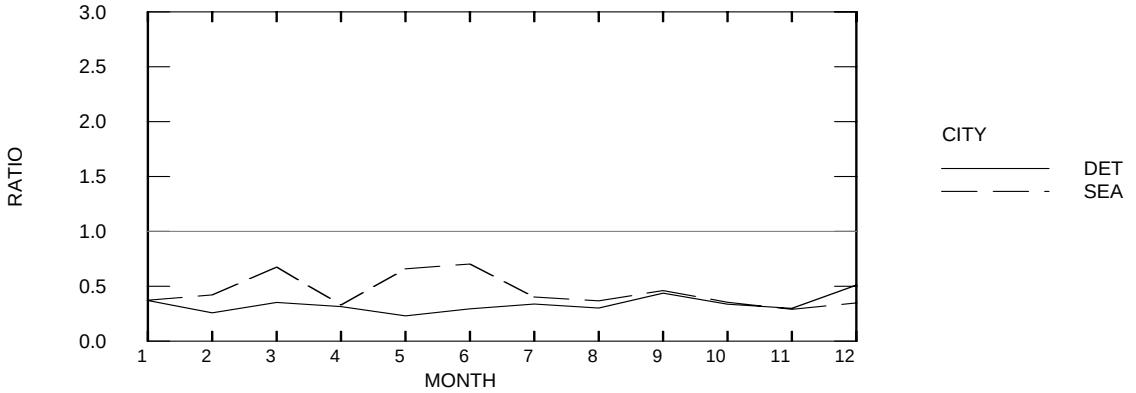

Figure B-7. Monthly average prediction to observed concentration ratios for lead TSP.

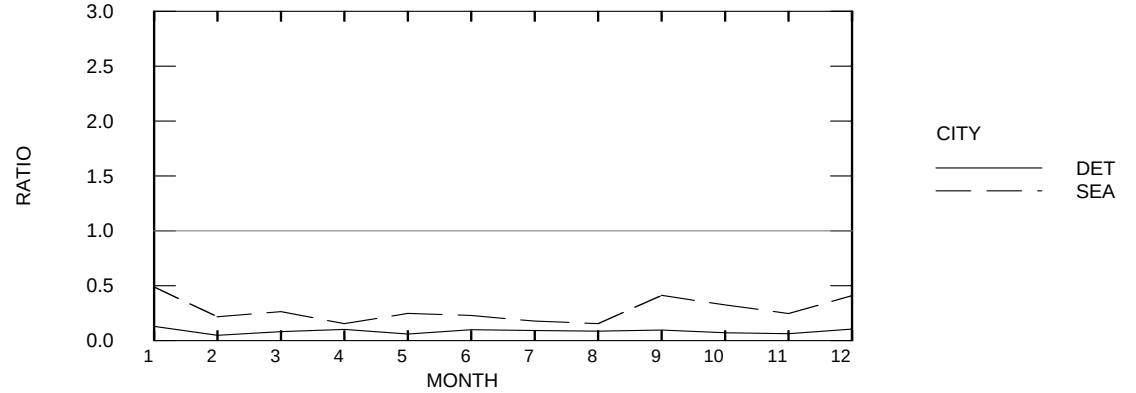

Figure B-8. Monthly average prediction to observed concentration ratios for manganese TSP.

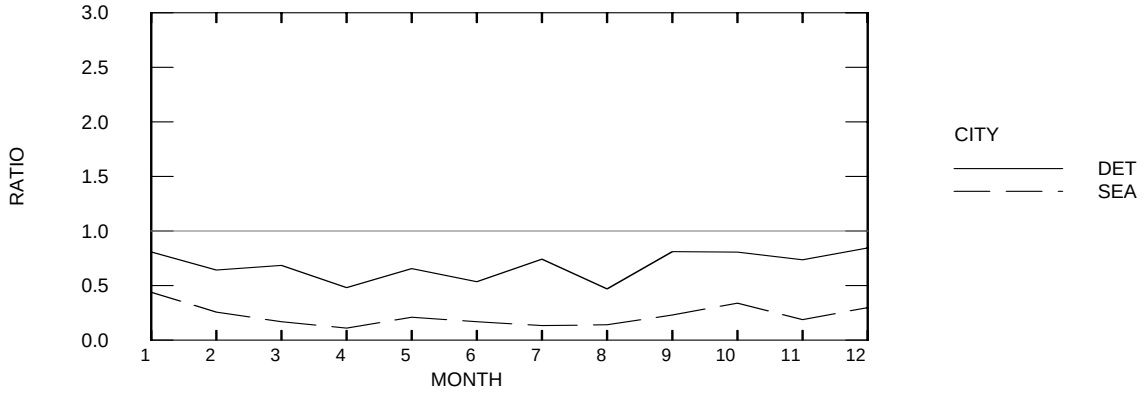

Figure B-9. Monthly average prediction to observed concentration ratios for nickel TSP.

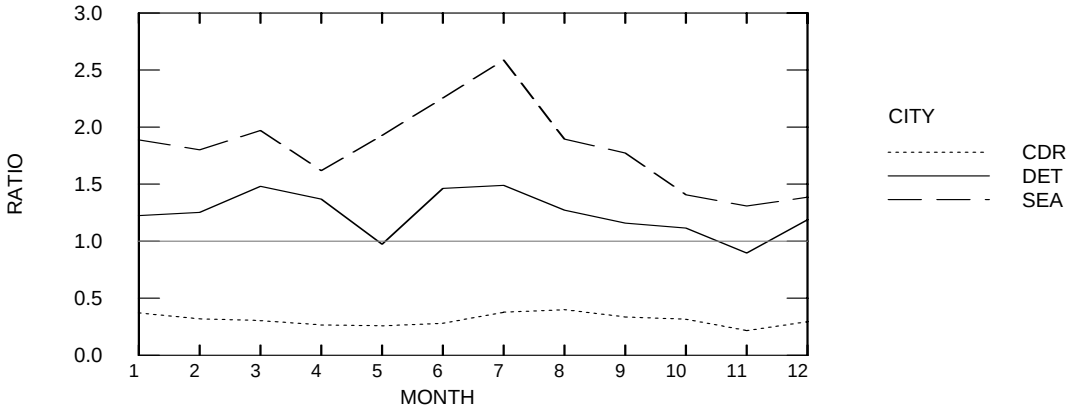

Figure B-10. Monthly average prediction to observed concentration ratios for 1,3-butadiene.

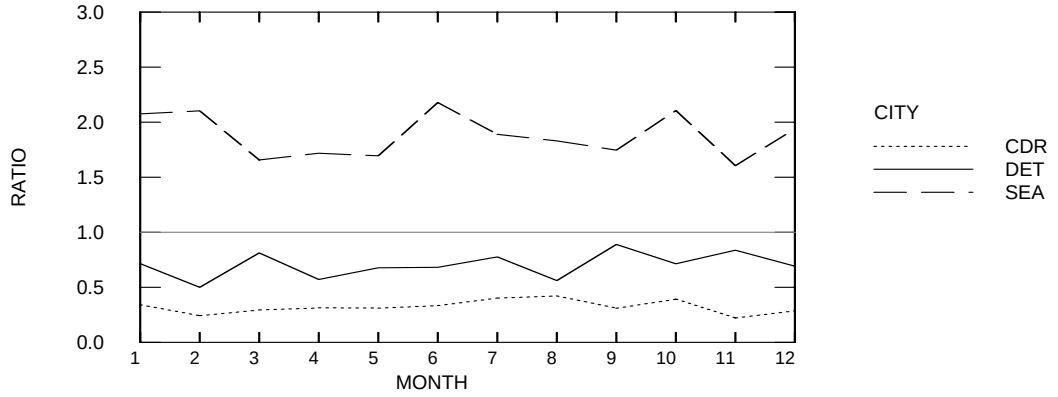

Figure B-11. Monthly average prediction to observed concentration ratios for benzene.

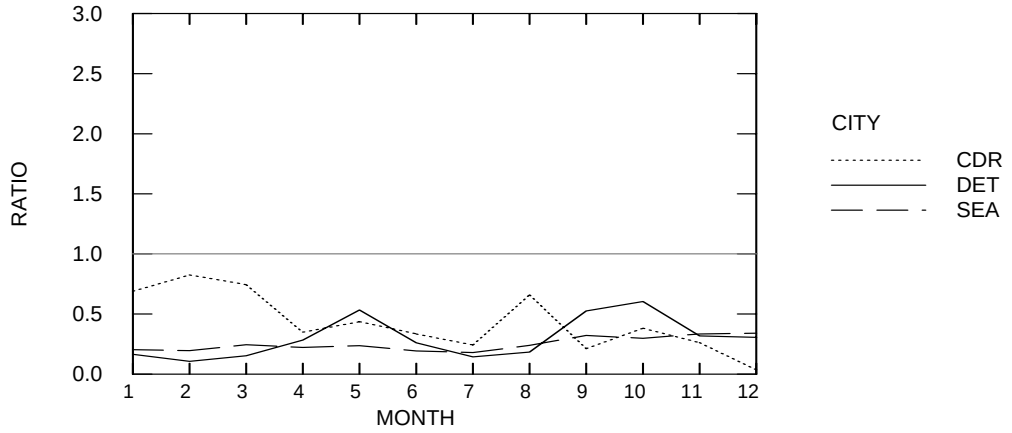

Figure B-12. Monthly average prediction to observed concentration ratios for methylene chloride.

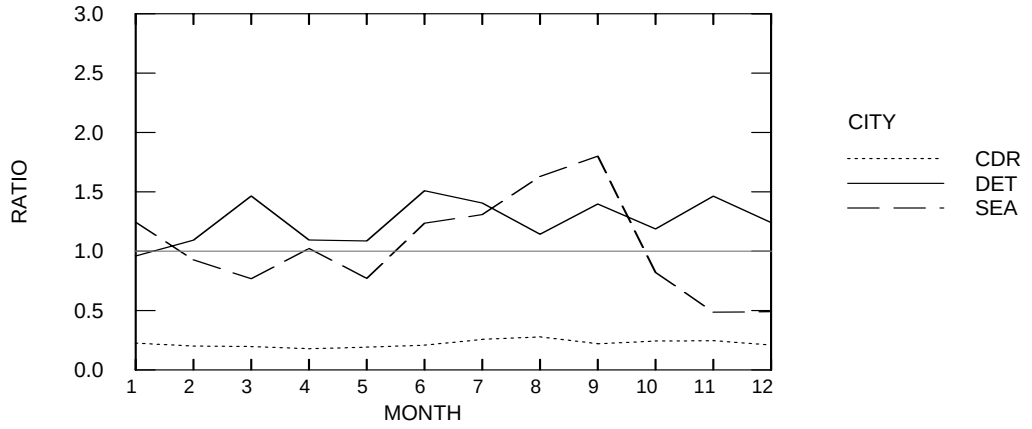

Figure B-13. Monthly average prediction to observed concentration ratios for Tetrachloroethylene.