Statistical Assessment of Benzene and 1,3-Butadiene in Ambient Air in the Houston Region

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June 2008

Executive Summary

A statistical analysis of 5, 7, and 10 year trends of ambient levels of benzene and 1,3-butadiene 1 hour automatic gas chromatograph concentrations in the Houston region was conducted to determine whether annual levels were statistically decreasing. Trend tests were conducted on seven statistical measures of each air pollutant at 10 monitoring sites. For benzene, the analysis revealed that of the 70 statistics (7 measures for 10 monitors), only 27% (19 statistical measures) showed improvement in the past five years despite increased regulation and controls. Four of the 10 monitoring sites showed no improvement in any statistic for the 5, 7 or 10 year trends. For 1,3-butadiene, the analysis revealed worsening trends at two monitors and extremely high 2006 annual mean concentrations at a third monitor. Statistically significant decreasing trends were detected early on in the ten year period but absent in the most recent five years. These results indicate that regulation and controls which were initially effective in improving air quality have hit a plateau.

Introduction

Concentrations of air toxics in the Houston region have been a source of controversy for many years. The debate has covered topics such as whether the biggest source is industry or vehicles, and the authority the City has to regulate toxic air pollution that comes from outside the city limits. Both of these issues contribute to the complexity of the air toxic problem in Houston: multiple air toxics coming from multiple sources, many of which are located in close proximity to residential areas.

This report presents an objective analysis of the annual trends of two pollutants of concern in Houston known to pose a definite risk of developing cancer. The results provide a retrospective look at the efficacy of air toxic regulation and controls as well as a baseline for measuring future progress to cleaner air.

Summary of Analysis and Results

In order to answer the question, "Have benzene and 1,3-butadiene levels in the Houston area decreased over time?" a statistical analysis of available benzene and 1,3-butadiene data for the past 10 years was conducted. Data were analyzed using seven statistical measures to evaluate trends at ten monitoring sites. For those monitors having sufficient data for 10, 7, and 5 years, a trend analysis was conducted to determine if air quality was improving.

The reporting of statistical findings of improvement in Figure 1 is objective but lenient. A monitor was classified as improving if any one of the seven statistical measures showed improvement. Therefore, a monitor could have six statistical measures that show no improvement with one that shows improvement and the monitor would still receive an "improvement detected" rating.

Overall results for benzene indicate six of the ten monitors evaluated show an improving trend in benzene concentrations, while four do not. Closer examination of the data reveals that more decreasing trends are found in the 10 year analysis than in the seven or five year analyses. Of ten monitors evaluated from 2003-2007, only half show improvement or a decreasing trend in any of the seven measures. For this same period, seventy statistics (7 measures at 10 monitors) were evaluated, but only 19 show improvement – a 27% improvement rate. The improvement rate for the seven year trend is even lower with only 3 of 21 statistics showing improvement, a meager 14%.

An additional analysis was done to rank twelve monitoring sites from most to least contaminated by benzene for the most recent year, 2007. This most to least ranking, based on current conditions, is key to interpreting the impact of a decreasing trend or no decreasing trend. A "contamination rank" was calculated based on an average of the rankings of seven statistical measures for 2007. Each monitor was given a rank for each of the seven statistical measures. All seven ranks for each monitor were then averaged to produce a single average rank for each monitor, the "contamination rank." Monitors were ordered in a table showing most contaminated at the top to least contaminated at the bottom (Figure 2).

Figure 1. Annual Average Benzene Concentrations for 2007 and 5 Year Trends (2003-2007)

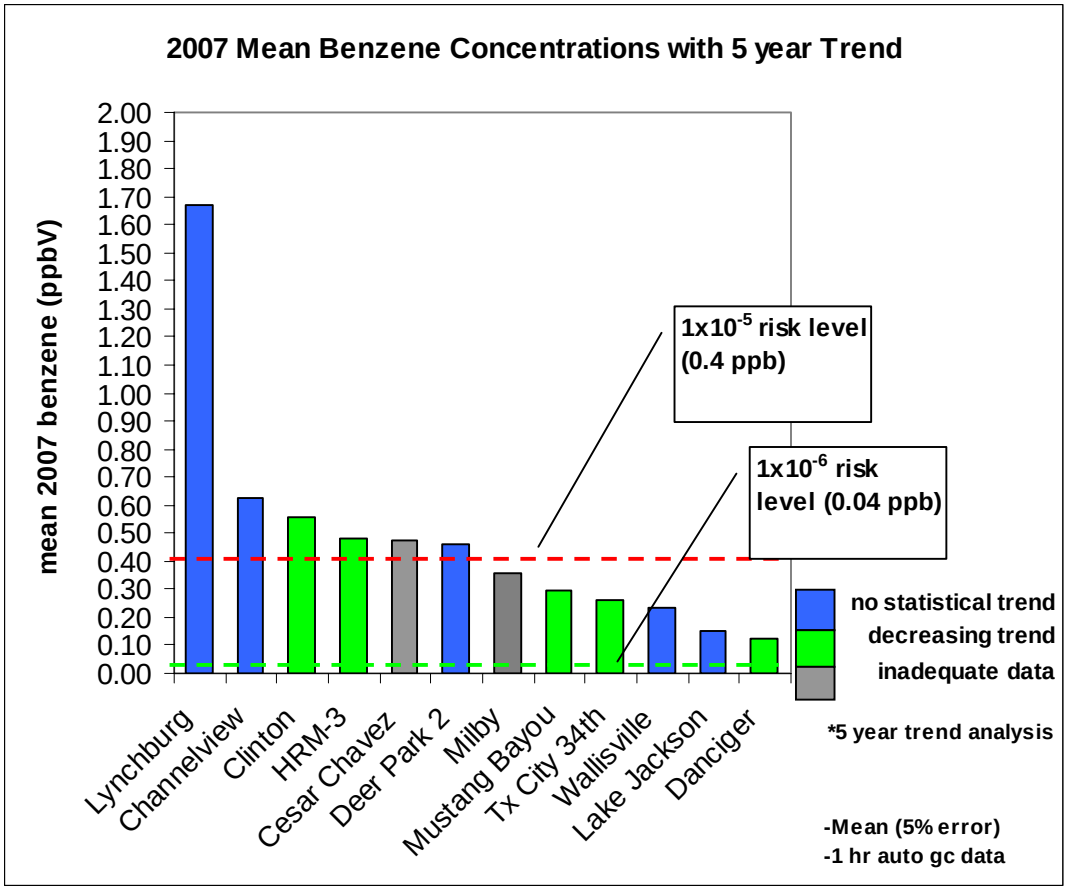

Figure 2. Ten, Seven and Five Year Trend Test Results for Benzene

Benzene		Trend Test Results Which Show Improvement			
Order of Most Contaminated	2007 contamination rank	10 yr Trend	7 yr Trend	5 yr Trend	Improvement detected?
Lynchburg	10.71			0/7	no
Channelview	10.71		0/7	0/7	no
Clinton	9.57	5/7	1/7	2/7	yes
HRM-3	8.71			5/7	yes
Cesar Chavez	7.71				
Deer Park 2	7.43	4/7	2/7	0/7	yes
Milby	6.86				
Mustang Bayou	4.86			4/7	yes
Tx City 34th	4.14			6/7	yes
Wallisville	3.43			0/7	no
Lake Jackson	1.71			0/7	no
Danciger	1.29			2/7	yes

ordering based on average rank of 7 statistical indicators
trend summary is the number of trend statistics showing statistically significant improvement in trend of air quality out of 7 trend tests on different statistics (α=0.05)
= not enough data

The situation for 1,3-butadiene is somewhat more encouraging. Only one monitor did not show improvement in the trend analysis of the 1 hour automatic gas chromatograph data and measurements at that site are close to an acceptable risk level (Figure 3). However, there were worsening trends for two statistical measures each at the Deer Park 2 and Wallisville monitors.

Figure 3. 2007 Mean 1,3-Butadiene Concentrations with 5 year Trend

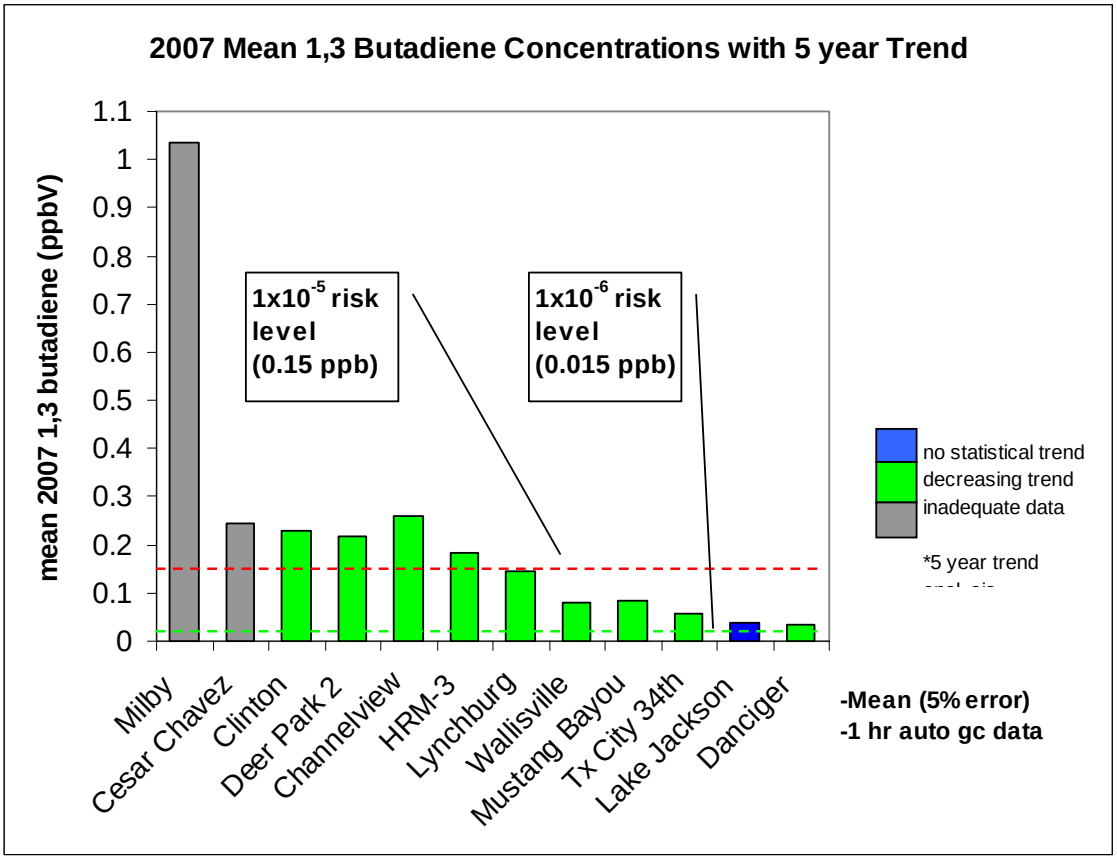

Figure 4. 1,3-Butadiene. Trend test results which show improvement

1,3-butadiene Trend Test Results Which Show Improvement

Order of Most Contaminated	2007 contamination rank	10 yr Trend	7 yr Trend	5 yr Trend	Improvement detected?
Milby	11.4				
Cesar Chavez	9.3				
Clinton	9.1	5/7	1/7	4/7	Yes
Deer Park 2	8.9	2/7	0/7	2/7	Yes
Channelview	8.4		3/7	2/7	Yes
HRM-3	7.7			5/7	Yes
Lynchberg	6.1			4/7	Yes
Wallisville	4.7			2/7	Yes
Mustang Bayou	4.4			2/7	Yes
Tx City 34th	3.6			1/7	Yes
Lake Jackson	1.6			0/7	No
Danciger	1.6			3/7	Yes

ordering based on average rank of 7 statistical indicators

trend summary is the number of trend statistics showing statistically significant

improvement in trend of air quality out of 7 trend tests on different statistics (=0.05)

= not enough data

*Wallisville and Deer Park 2 have one 5 yr trend of worsening conditions

*Deer Park 2 has three 7 yr trends of worsening conditions

*Deer Park 2 has one 10 yr trend of worsening conditions

Extremely high annual mean concentrations of 1,3-butadiene are measured at Milby Park. The maximum concentration measured at Milby Park in 2006 was thirteen times greater than the previous maximum measured in the Houston region. One hour gas chromtograph data from Milby has only been available since 2005, so no trend analyses were conducted*. However, concentrations of 1,3-butadiene at Milby Park in the most recent three years consistently exceed the one in one-hundred thousand health risk level for all statistical measures, with only one exception. (*Note: Canister data for Milby Park dating back to 1999 shows improvement. However, this trend analysis focuses only on the 1 hour gas chromatograph data.)

The trend analyses and the statistical measures are discussed in detail below.

Benzene trend analysis

The following seven statistical measures were calculated for each of the years that data were available at each site and were used for the trend analysis: mean at 95th upper confidence limit (statistically assured average), maximum concentration, median concentration (midpoint), median of concentrations above the 1x10^{-5} limit health limit, percent of time above 1x10^{-4} health limit, percent of time above 1x10^{-5} health limit, and percent of time below 1x10^{-6} health limit.

A trend analysis using the Mann Kendall test was conducted on the statistical measures for the most recent 5, 7 and 10 years to determine increases and decreases in benzene concentrations over time. Decreasing trends are counted as improvements except for percent of time below 1x10^{-6} health limit, which is counted as an improvement if it has an increasing trend. The number of improvements is listed in the numerator of the fractions in Figure 2. If even one of the trends measured in the past 10 years showed a decrease, that monitor was considered as "improving."

Evaluation of annual data for 2007 indicated that the Lynchburg Ferry and Channelview sites ranked as "most contaminated" for seven benzene measures, and the Lake Jackson and Danciger sites were least contaminated (Figure 2 and Appendix Figure P-1). Only two sites, Clinton and Deer Park 2, had sufficient annual data for a 10-year trend analysis. Both showed improvement in several of the seven measures in the 10 and 7-year trend analyses. Clinton showed improvement in the 5-year trend analysis, but the Deer Park 2 monitor showed no improvement.

Although an improvement in the ten year trend of benzene concentrations is seen at Clinton and Deer Park 2, improvement was detected at only half of the ten sites evaluated for the last 5 years. In addition to the Clinton site, HRM-3, Mustang Bayou, Texas City 34th St., and Danciger showed improvement. HRM-3 and Texas City 34th St. had the most improvement with 5 and 6 of 7 measures showing decreases, respectively. Mustang Bayou had improvement in 4 of 7 measures, and Clinton and Danciger in 2 of 7.

In addition to Deer Park 2, four other monitors showed no improvement in the past 5 years: Lynchburg Ferry, Channelview, Wallisville, and Lake Jackson. However, annual mean benzene concentrations at Wallisville and Lake Jackson have remained below $1x10^{-5}$ (ten in a million) risk level for the past 5 years (Appendix Figure A-1); therefore improvement in any of the seven measures would be unexpected. In contrast, although Deer Park and Clinton monitors show statistical improvement (Figure 2), annual mean benzene concentrations at these two monitors have remained above the $1x10^{-5}$ (10 in a million) risk level for the past ten years (Appendix Figure A-1).

Acceptable benzene risk levels at Lake Jackson and improving five-year trends at Mustang Bayou and Danciger are consistent with the values for the percent of the year below the $1x10^{-6}$ (one in a million) risk level (Appendix Figure H-1). In 2004, Lake Jackson experienced acceptable risk levels for 42% of the year and from 22% to 25% for years 2003, 2005, 2006 and 2007. In addition, Mustang Bayou and Danciger had acceptable levels of benzene for at least 10% of the last five years.

Lynchburg Ferry and Channelview sites ranked highest for annual benzene measures in 2007 and have shown no improvement in the past 5-7 years in any of the seven measures evaluated.[1] When comparing annual means (Appendix Figure A-1) and medians (Appendix Figure D-1) at all ten monitors for each of the years that data are available, the annual mean is higher in all cases than the median, indicating that values greater than the middle point are affecting the mean.

Maximum one-hour values are in the $1x10^{-4}$ (100 in a million) risk range for all but two years at two different sites (Appendix Figure B-1). At Lynchburg Ferry, maximum values each year have been greater than 400 ppbV/hour for the past five years. The acceptable $1x10^{-6}$ risk level is 0.04 ppbV.

By looking only at the data that exceed the $1x10^{-5}$ (10 in a million) risk level, one can see the severity to which the concentrations exceed the limit at Lynchburg Ferry. In 2003, 2005 and 2006 the median of those concentrations was three times the 10 in a million risk level (Appendix Figure E-1) and benzene concentrations exceeded the $1x10^{-4}$ (100 in a million) risk level for more than 10% of the year (Appendix Figure F-1). The $1x10^{-5}$ (10 in a million) risk level was exceeded for more than 50% of the year in 2003 and 2005 and more than 40% for 2004, 2006 and 2007 (Appendix Figure G-1).

In the past five years, the $1x10^{-5}$ (10 in a million) risk level was also exceeded for more than 50% of the year at HRM-3 and Channelview monitors in 2003 (Appendix Figure G-1).

1,3-Butadiene trend analysis

A similar analysis conducted for available data on 1,3-butadiene at the same ten monitors gave a more positive outlook than was seen for benzene. Only the Lake Jackson monitor did not show a decreasing trend for 1,3-butadiene over the past five years (Figure 3) whereas four monitors did not show a decreasing trend for benzene. In ranking the twelve sites for 2007, Milby ranked

[1] In 2001, the Channelview site had only a 21% frequency of detection.

highest for the seven 1,3-butadiene measures and Lake Jackson and Danciger were again the lowest (Figure 4 and Appendix Figure P-2).

Clinton and Deer Park 2 were the only two sites that had sufficient data for a 10-year trend analysis and both showed improvement in several of the seven measures in the 10, and 5-year trend analyses. The Deer Park 2 site showed no improvement in any of the seven measures in the 7-year trend analysis and the Clinton site showed improvement in only one measure. Three of seven measures showed improvement at the Channelview site in the 7-year trend analysis.[2] In the five year trend analysis, all ten sites showed improvement for measures of 1,3-butadiene except Lake Jackson. As was the case with benzene, annual mean 1,3-butadiene concentrations at Lake Jackson have remained below $1x10^{-5}$ (ten in a million) risk level for the past five years and the seven statistical measures would not be expected to show much improvement. HRM-3 showed the most improvement with 5 of 7 measures. Clinton and Lynchburg Ferry had improvement in 4 of 7 measures, and Danciger in 3 of 7. Twenty-five of the seventy statistics evaluated for 1, 3-butadiene showed improvement in the past five years versus nineteen for the benzene statistics (Figure 4) Five years of data are not available for Milby Park or Cesar Chavez monitors, so they are not included in the trend analysis.

One major difference between the benzene and 1,3-butadiene trend analysis is the appearance of "worsening" trends for 1,3-butadiene. The Deer Park 2 monitor had worsening trends for percent of year below $1x10^{-6}$ for the 10, 7, and 5 year trend analyses, and also for percent of year above $1x10^{-5}$ for the 7 year trend (Appendix Figures H-2 and G-2). The Wallisville monitor had one worsening trend for the maximum statistic for the five year trend analyses. All of these worsening trends were caused by increases in statistical measures in 2006. No worsening trends were seen in the benzene analysis.

On a more positive note, one site had a risk level of less than one in a million ($1x10^{-6)}$ for one of the statistical measures. The annual median for Mustang Bayou was 0.01 ppbV for 2003 and 0 ppbV for 2006 (Appendix Figure D-2). The remaining three years, 2004, 2005 and 2007 had an annual median of 0.02 ppbV. The acceptable risk level for 1,3-butadiene is 0.015 ppbV.

Both the highest annual mean concentration of 1,3-butadiene (Appendix Figure A-2) and the greatest annual maximum concentration (1611.25 ppbV) were measured at the Milby Park monitor in 2006. This value is 13 times greater than the second highest maximum (121.87 ppbV), which was measured at Lynchburg Ferry in 2005 (Appendix Figure B-2).

Looking only at the highest concentrations measured at Milby Park, those that exceed the $1x10^{-5}$ (10 in a million) risk level, gives a better picture of the severity of 1,3-butadiene measures. In 2005 and 2007 the median of those concentrations was six times the 10 in a million risk level and four times in 2006 (Appendix Figure E-2). In 2005 and 2007, 1,3-butadiene concentrations exceeded the $1x10^{-5}$ (10 in a million) risk level for more than 50% of the year (Appendix Figure G-2) and for 49% of 2006. Milby Park exceeded the $1x10^{-4}$ (100 in a million) risk level for 22%, 13% and 19% of the year in 2005, 2006, and 2007 respectively (Appendix Figure F-2). The

[2] In 2001, the Channelview site had only a 21% frequency of detection.

Lynchburg Ferry and Deer Park monitors also exceeded $1x10^{-5}$ (10 in a million) risk level for more than 50% of the year for one of the past five years.

Figure 5. Map of Houston area monitors with automated gas chromatographs

Methods

This analysis is a statistical assessment of 10 years (1998-2007) of all of the available benzene one-hour automated gas chromatograph (autoGC) data in the Houston region. All concentrations are in parts per billion by volume (ppbV). Each year is evaluated in terms of 8 statistical measures for both benzene and 1,3-butadiene: mean at 95th upper confidence, arithmetic mean (Appendix Figure C-1 and C-2), maximum, median, median of concentrations above the $1x10^{-5}$ limit risk level, percent of time above $1x10^{-4}$ risk level, percent of time above $1x10^{-5}$ risk level, and percent of time below $1x10^{-6}$ risk level. A summary of the statistics generated for the 8 measures at twelve monitors, including sample distribution for benzene and 1,3-butadiene, is presented in Appendix Figure I-1 and I-2.

The percent of each year having missing data or non-detectable values was calculated to ensure that the years are representative. Data that were below the detection limit of the equipment and could not be measured were replaced with a value that is one-half the detection limit. This more accurate method is recommended by the EPA for handling data below the detection limit. (Appendix Figures Q-1 and Q-2, R-1 and R-2, S-1 and S-2).

All monitors had some years when frequency of detection was less than 80% except the Cesar Chavez and Milby Park monitors that were only analyzed for 2007. In 2003, all monitors except the Channelview monitor had less than 80% frequency of detection (Appendix Figures R-1 and R-2). In those years when frequency of detection was between 50% and 80%, data was interpreted cautiously. For the five year trend analysis, a lower frequency of detection would tend toward less improvement because higher concentrations would be less likely to be measured. The low frequency of detection in 2003 would have less of an effect on the ten year trend analysis.

The trend of each statistic was evaluated using the EPA recommended Mann Kendall test for trend at the 5% significance level, one sided. The Mann Kendall test is a widely accepted trend test especially suited for environmental data (Appendix Figure T-1 and T-2).

Only seven of the eight statistics evaluated at each site were used in the ranking and trend analysis; the arithmetic mean rank was not used because it duplicates the mean rank at 95% confidence. A trend test (Mann Kendall) was conducted for each of the seven statistics at monitors with adequate data (α=0.05). Trend test results calculated from the Mann Kendall test at 10, 7 and 5 years are presented in Appendix Figures J-1 and J-2, L-1 and L-2, and N-1 and N-2 respectively. Improvements in benzene measures for the same trend analyses are listed in Appendix Figures K-1 and K-2, M-1 and M-2, and O-1 and O-2.

The health levels are derived from the EPA Office of Air Quality Planning and Standards unit risk levels (http://cfpub.epa.gov/ncea/iris/index.cfm?fuseaction=iris.showSubstanceList. 5/30/2008). The $1x10^{-6}$ risk level for benzene is 0.04 ppbV and for 1,3-butadiene is 0.015 ppbV.

Figure 5 shows the sites with automated gas chromatographs. All of these sites are in the Houston region. Clinton, Milby and Cesar Chavez are in the city limits, HRM-3 is just outside of the city limits and Channelview, Deer Park 2, Wallisville, and Lynchburg are close to the Houston Ship Channel and within Harris County. Texas City, Mustang Bayou, Lake Jackson, and Danciger are located along the Gulf Coast but within the 8-county metropolitan statistical area and considered to be part of the Houston region. The data were obtained from the Texas Commission on Environmental Quality that maintains a network of monitors in the Houston region.

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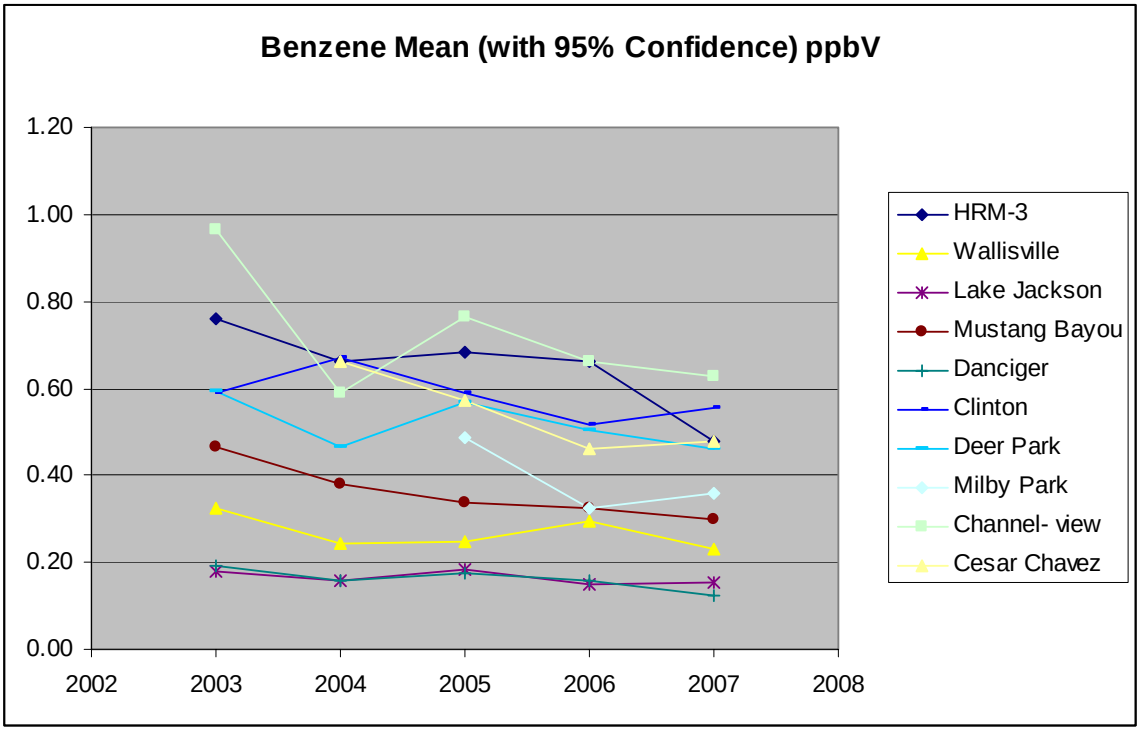
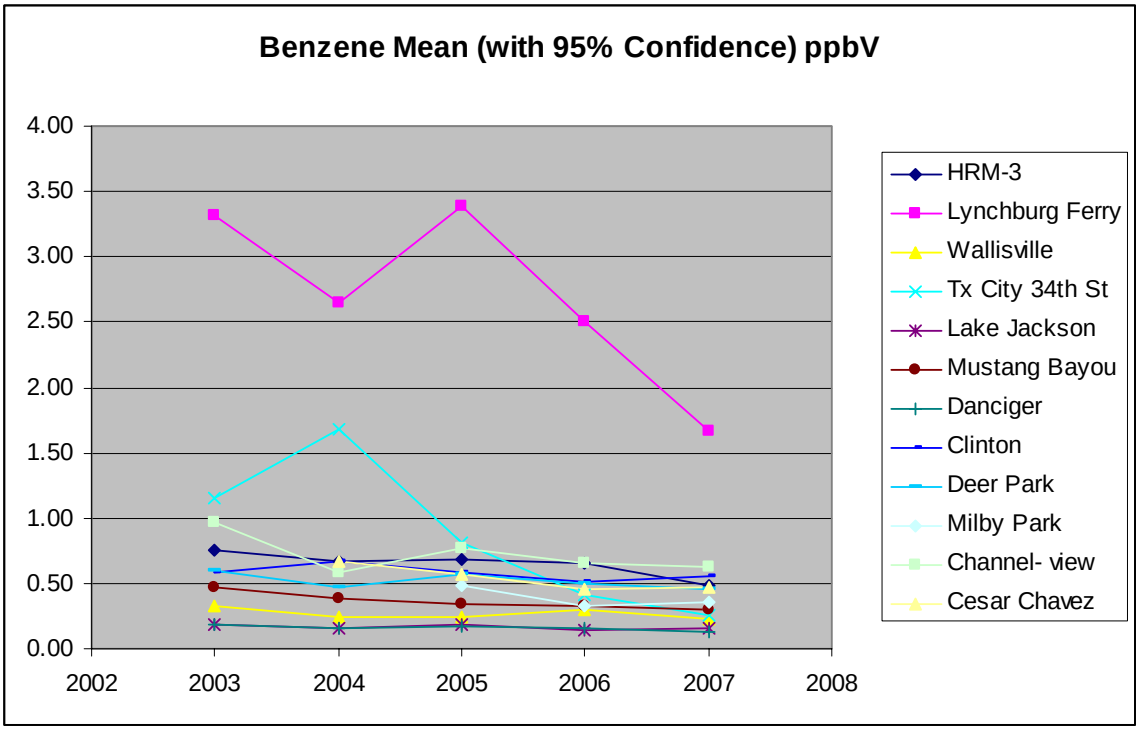
Figure A-3. Benzene and 1,3-Butadiene Combined Inhalation Risk

Figure A-1. Benzene mean with 95% confidence





Benzene Mean (with 95% Confidence) ppbV

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				1.16		0.76	0.66	0.68	0.66	0.48
Lynchburg Ferry						3.32	2.65	3.39	2.51	1.67
Wallisville						0.33	0.24	0.25	0.29	0.23
Tx City 34th St						1.15	1.68	0.80	0.41	0.26
Lake Jackson						0.18	0.16	0.18	0.15	0.15
Mustang Bayou						0.47	0.38	0.34	0.32	0.30
Danciger						0.19	0.16	0.18	0.16	0.13
Clinton	0.72	0.75	0.82	0.68	0.58	0.59	0.67	0.59	0.52	0.56
Deer Park	0.66	0.78	0.47	0.55	0.64	0.60	0.46	0.57	0.50	0.46
Milby Park								0.49	0.33	0.36
Channel-view				0.91	0.68	0.97	0.59	0.76	0.66	0.63
Cesar Chavez							0.66	0.57	0.46	0.48

This statistic is the upper 95th confidence limit of the annual mean of the hourly automatic gas chromatograph data. Although the true mean cannot be known without analyzing all of the air, the probability that the true mean is higher than this number is held to 5%.

red = $1x10^{-4}$ risk, 4.0 ppbV, or greater

orange =$1x10^{-5}$ risk, 0.4 ppbV, or greater

yellow =$1x10^{-6}$ risk, 0.04 ppbV, or greater

green =less than $1x10^{-6}$ risk

blank cells indicate no data were reported for the time frame

Figure B-1. Benzene maximum

Benzene Maximum ppbV

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				13.64		25.37	31.74	153.96	296.58	44.12
Lynchburg Ferry						525.58	1551.92	770.78	418.98	912.74
Wallisville						9.28	7.39	7.22	8.88	10.67
Tx City 34th St						115.86	177.01	179.24	57.95	14.14
Lake Jackson						4.31	19.92	3.79	8.9	3.5
Mustang Bayou						10.15	13.51	8.19	15.52	13.83
Danciger						4.49	6.83	6.23	5.4	2.68
Clinton	113.68	77.59	52.19	43.53	23.82	27.52	73.54	26.09	8.52	66.93
Deer Park	32.56	27.03	13.37	25.68	15.63	17.03	16.2	23.6	20.85	41.8
Milby Park								25.59	21.1	21.03
Channel-view				44.31	17.75	70.95	23.84	133.48	26.57	25.68
Cesar Chavez							20.93	15	32.21	17.44

This statistic is the maximum concentration of the 1 hour annual data.

red = $1x10^{-4}$ risk, 4.0 ppbV, or greater

orange =$1x10^{-5}$ risk, 0.4 ppbV, or greater

yellow =$1x10^{-6}$ risk, 0.04 ppbV, or greater

green =less than $1x10^{-6}$ risk

blank cells indicate no data were reported for the time frame

Figure C-1. Benzene mean

Benzene Mean ppbV

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				1.11		0.74	0.65	0.64	0.58	0.46
Lynchburg Ferry						2.84	2.23	3.02	2.27	1.44
Wallisville						0.32	0.24	0.24	0.29	0.23
Tx City 34th St						1.04	1.55	0.74	0.39	0.25
Lake Jackson						0.17	0.15	0.18	0.14	0.15
Mustang Bayou						0.45	0.37	0.33	0.31	0.29
Danciger						0.18	0.15	0.17	0.15	0.12
Clinton	0.69	0.71	0.79	0.65	0.57	0.57	0.64	0.57	0.50	0.54
Deer Park	0.64	0.75	0.46	0.53	0.63	0.58	0.45	0.54	0.49	0.44
Milby Park								0.47	0.31	0.35
Channel-view				0.85	0.66	0.93	0.57	0.71	0.64	0.61
Cesar Chavez							0.64	0.56	0.45	0.46

This statistic is the the annual sample mean of the hourly automatic gas chromatograph data without confidence. It is used in conjunction with the number of samples collected and the standard deviation of the samples to calculate the upper confidence limit of the true mean.

red = $1x10^{-4}$ risk, 4.0 ppbV, or greater

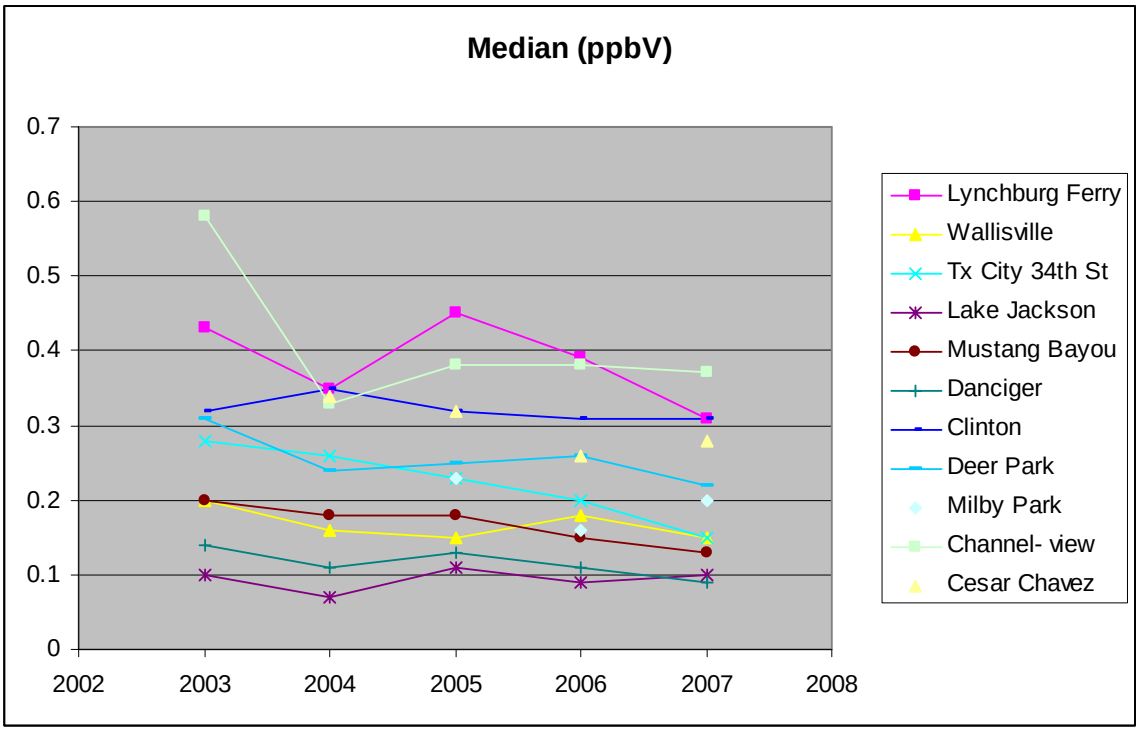
orange =$1x10^{-5}$ risk, 0.4 ppbV, or greater

yellow =$1x10^{-6}$ risk, 0.04 ppbV, or greater

green =less than $1x10^{-6}$ risk

blank cells indicate no data were reported for the time frame

Figure D-1. Benzene median



Benzene Median ppbV

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				0.83		0.44	0.39	0.39	0.29	0.29
Lynchburg Ferry						0.43	0.35	0.45	0.39	0.31
Wallisville						0.2	0.16	0.15	0.18	0.15
Tx City 34th St						0.28	0.26	0.23	0.2	0.15
Lake Jackson						0.1	0.07	0.11	0.09	0.1
Mustang Bayou						0.2	0.18	0.18	0.15	0.13
Danciger						0.14	0.11	0.13	0.11	0.09
Clinton	0.41	0.37	0.5	0.37	0.31	0.32	0.35	0.32	0.31	0.31
Deer Park	0.38	0.37	0.29	0.26	0.37	0.31	0.24	0.25	0.26	0.22
Milby Park								0.23	0.16	0.2
Channel-view				0.54	0.49	0.58	0.33	0.38	0.38	0.37
Cesar Chavez							0.34	0.32	0.26	0.28

This statistic is the middle 50% of the data. It is a better indicator of central tendancy of the data distribution than the mean for skewed environmental datasets.

red = $1x10^{-4}$ risk, 4.0 ppbV, or greater

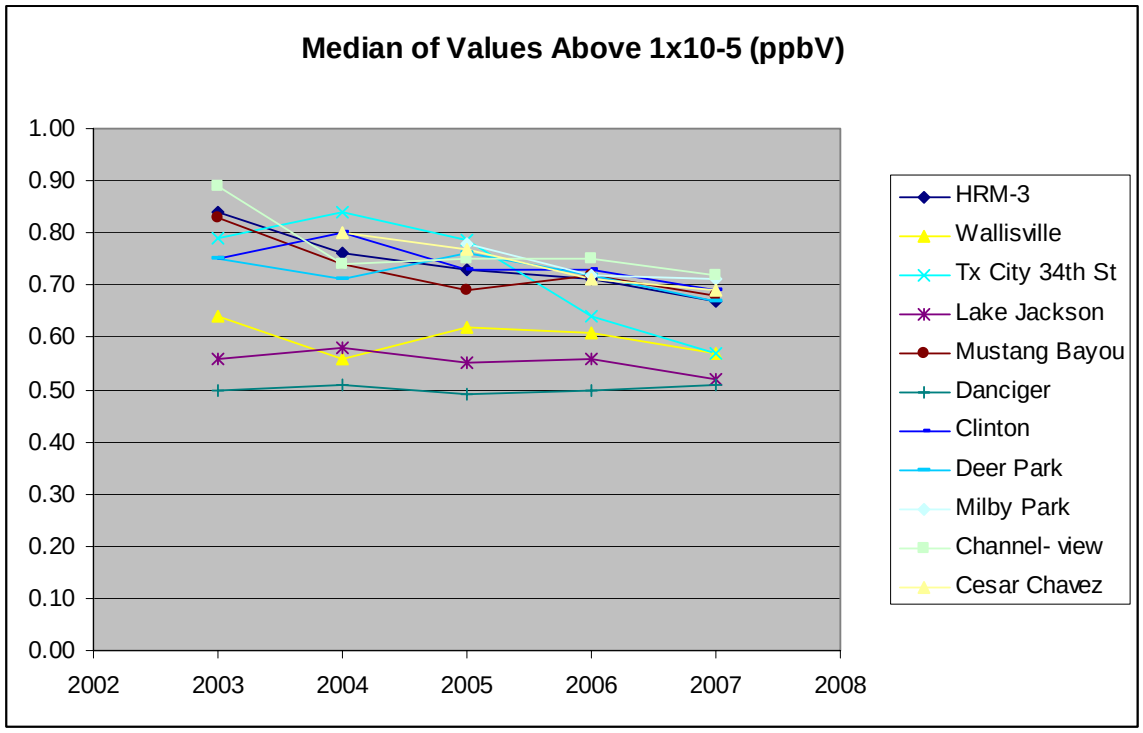
orange =$1x10^{-5}$ risk, 0.4 ppbV, or greater

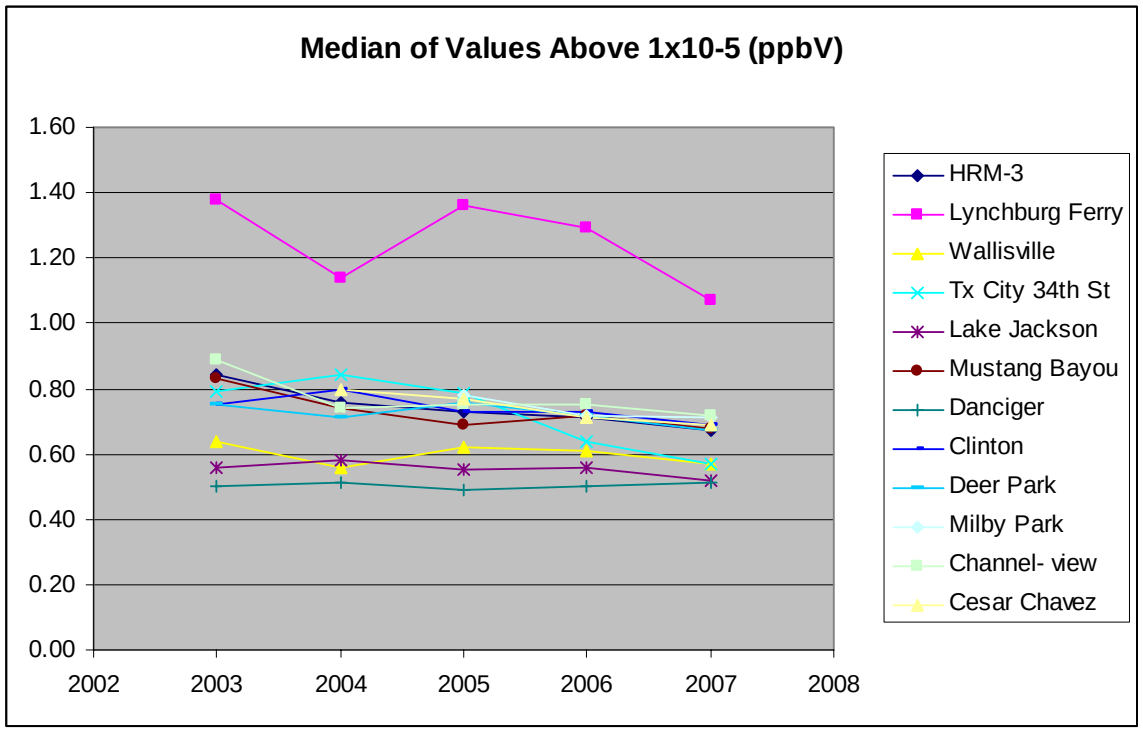
yellow =$1x10^{-6}$ risk, 0.04 ppbV, or greater

green =less than $1x10^{-6}$ risk

blank cells indicate no data were reported for the time frame

Figure E-1. Benzene median of concentrations above 1 x 10^{-5} risk





Benzene Median of Concentrations above $1x10^{-5}$ risk ppbV

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				1.10		0.84	0.76	0.73	0.71	0.67
Lynchburg Ferry						1.38	1.14	1.36	1.29	1.07
Wallisville						0.64	0.56	0.62	0.61	0.57
Tx City 34th St						0.79	0.84	0.79	0.64	0.57
Lake Jackson						0.56	0.58	0.55	0.56	0.52
Mustang Bayou						0.83	0.74	0.69	0.72	0.68
Danciger						0.50	0.51	0.49	0.50	0.51
Clinton	0.77	0.80	0.73	0.78	0.78	0.75	0.80	0.73	0.73	0.69
Deer Park	0.70	0.80	0.69	0.76	0.73	0.75	0.71	0.76	0.72	0.67
Milby Park								0.78	0.72	0.71
Channel-view				0.84	0.68	0.89	0.74	0.75	0.75	0.72
Cesar Chavez							0.80	0.77	0.71	0.69

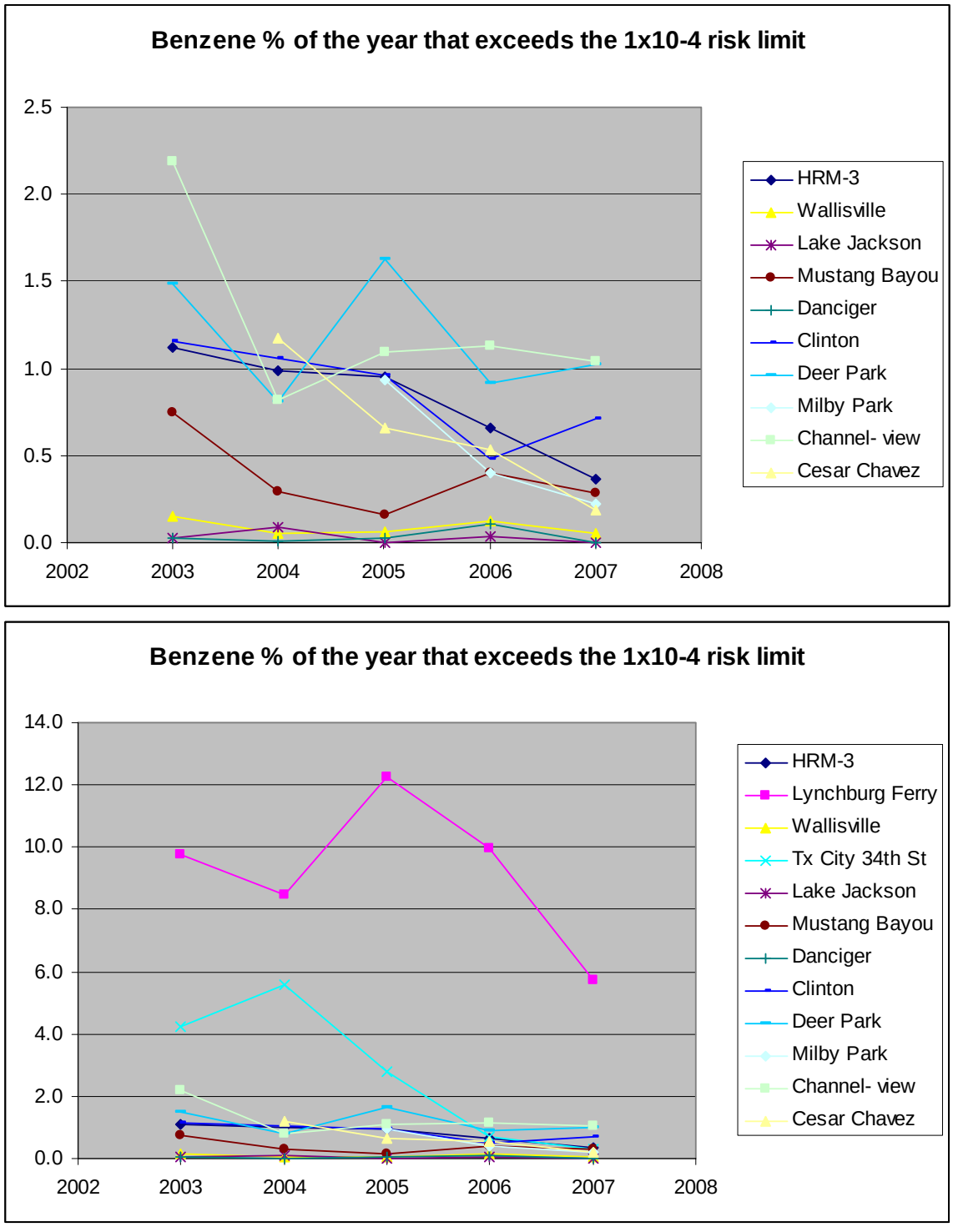
This statistic is the middle 50% of the data which exceeds the $1x10^{-5}$ risk limit. It is an indicator of the severity to which the concentrations exceed the limit.

pink = concentrations are 3x the $1x10^{-5}$ risk, 1.2 ppbV, or greater

rose = concentrations are 2x the $1x10^{-5}$ risk, 0.8 ppbV, or greater

blank cells indicate no data were reported for the time frame

Figure F-1. Benzene % of the year that exceeds $1x10^{-4}$ risk limit



Benzene % of the year that exceeds the $1x10^{-4}$ risk limit

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				2		1	1	1	1	0
Lynchburg Ferry						10	8	12	10	6
Wallisville						0	0	0	0	0
Tx City 34th St						4	6	3	1	0
Lake Jackson						0	0	0	0	0
Mustang Bayou						1	0	0	0	0
Danciger						0	0	0	0	0
Clinton	1	2	2	1	1	1	1	1	0	1
Deer Park	1	3	1	1	1	1	1	2	1	1
Milby Park								1	0	0
Channel-view				2	1	2	1	1	1	1
Cesar Chavez							1	1	1	0

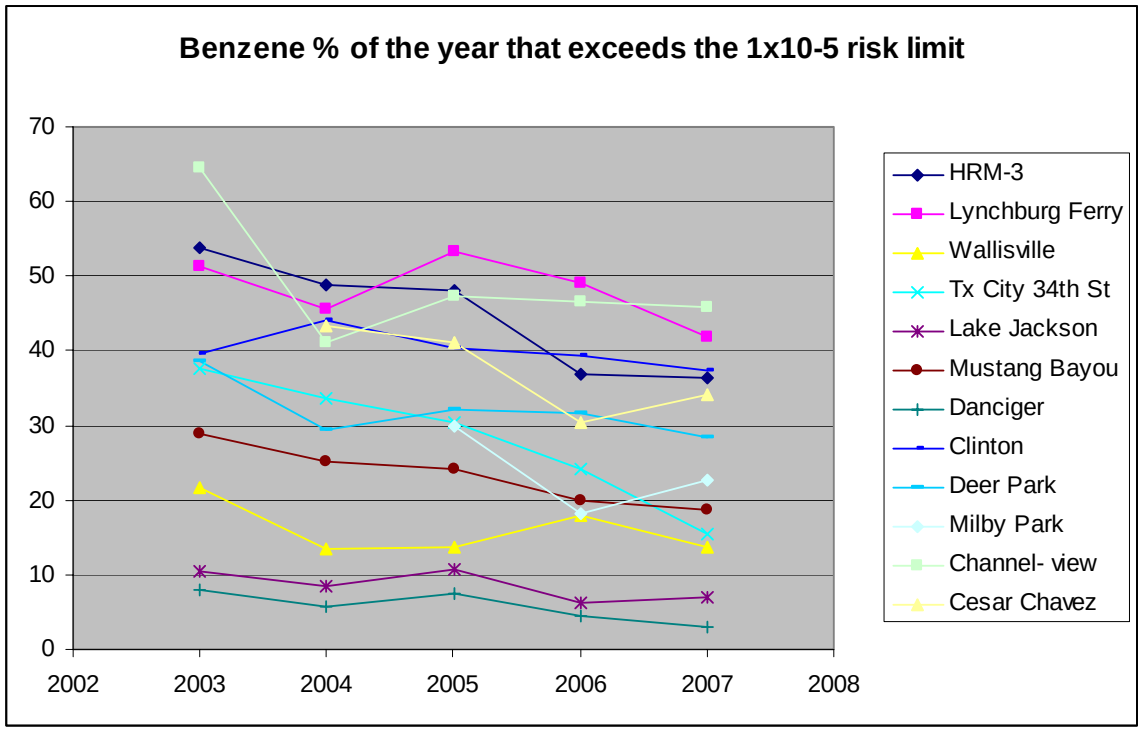
This statistic is the percent of the year that hourly concentrations exceeded the $1x10^{-4}$ risk limit. This is an indicator of how often very extreme values were experienced.

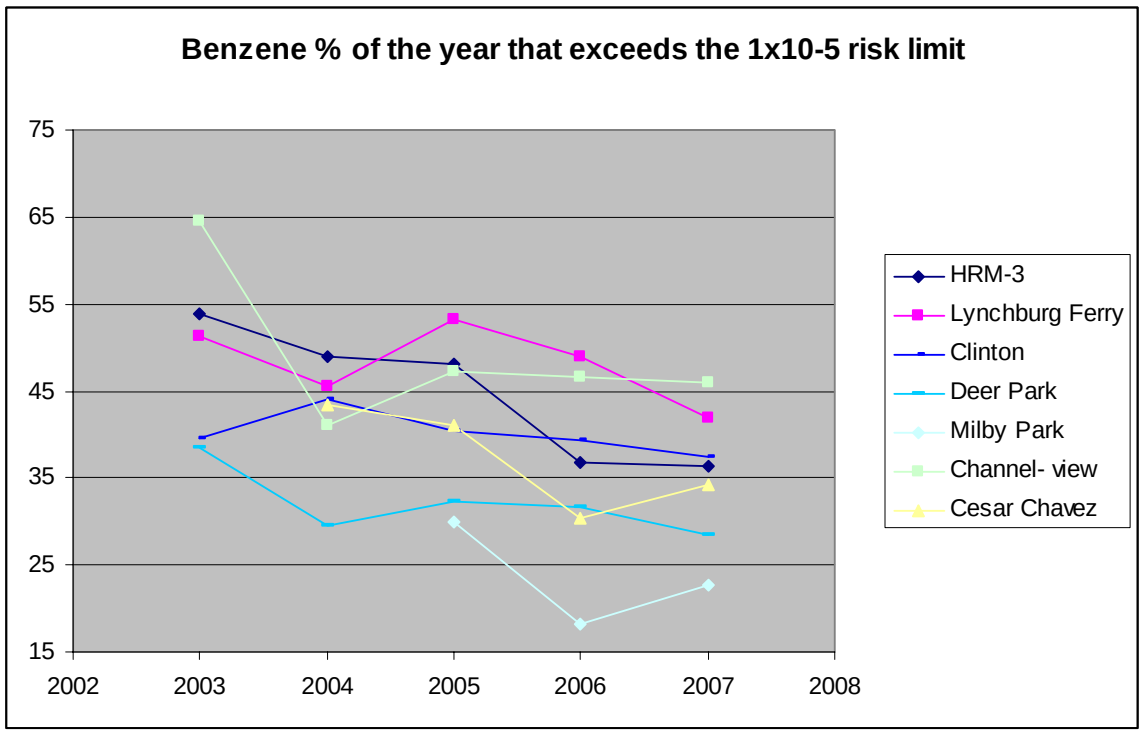
dk gray = percent of year with 10% or greater extreme values

lt gray = percent of year with 5% or greater extreme values

blank cells indicate no data were reported for the time frame

Figure G-1. Benzene % of the year that exceeds $1x10^{-5}$ risk limit





Benzene % of the year that exceeds the $1x10^{-5}$ risk limit

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				77		54	49	48	37	36
Lynchburg Ferry						51	46	53	49	42
Wallisville						22	13	14	18	14
Tx City 34th St						38	34	30	24	15
Lake Jackson						11	9	11	6	7
Mustang Bayou						29	25	24	20	19
Danciger						8	6	7	5	3
Clinton	50	47	61	47	39	40	44	40	39	37
Deer Park	47	46	34	35	45	39	29	32	32	28
Milby Park								30	18	23
Channel-view				61	61	65	41	47	47	46
Cesar Chavez							43	41	30	34

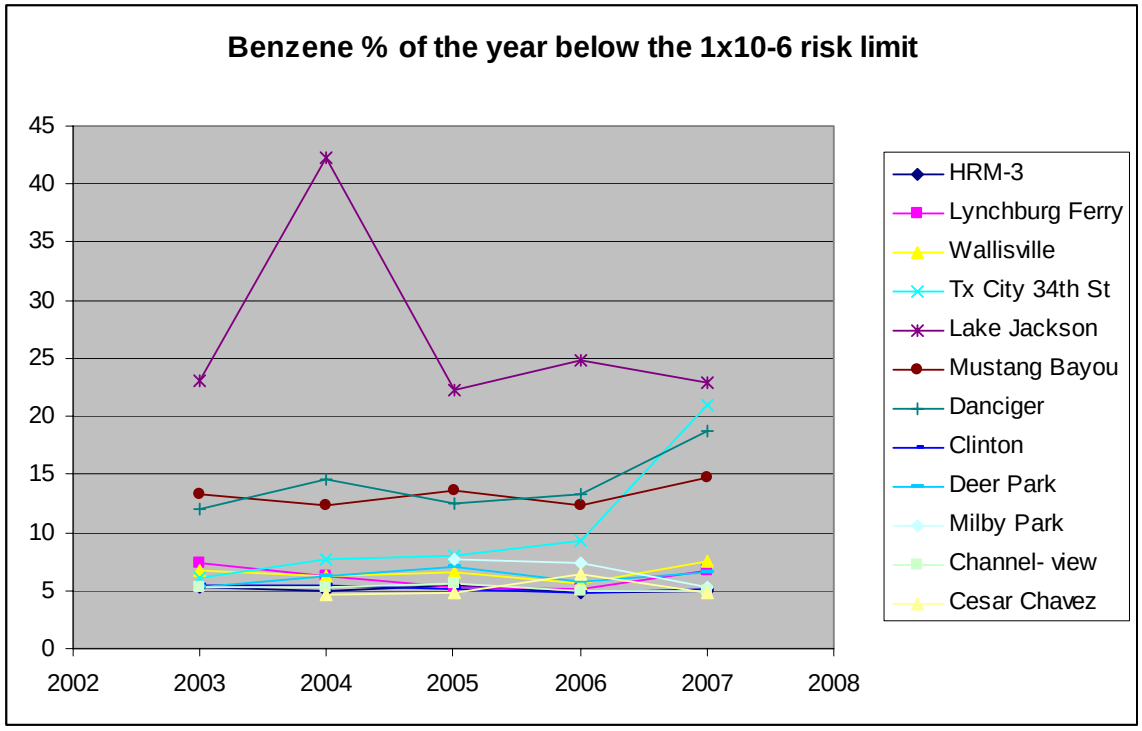
This statistic is the percent of the year that hourly concentrations exceeded the $1x10^{-5}$ risk limit. This is an indicator of how often extreme values were experienced.

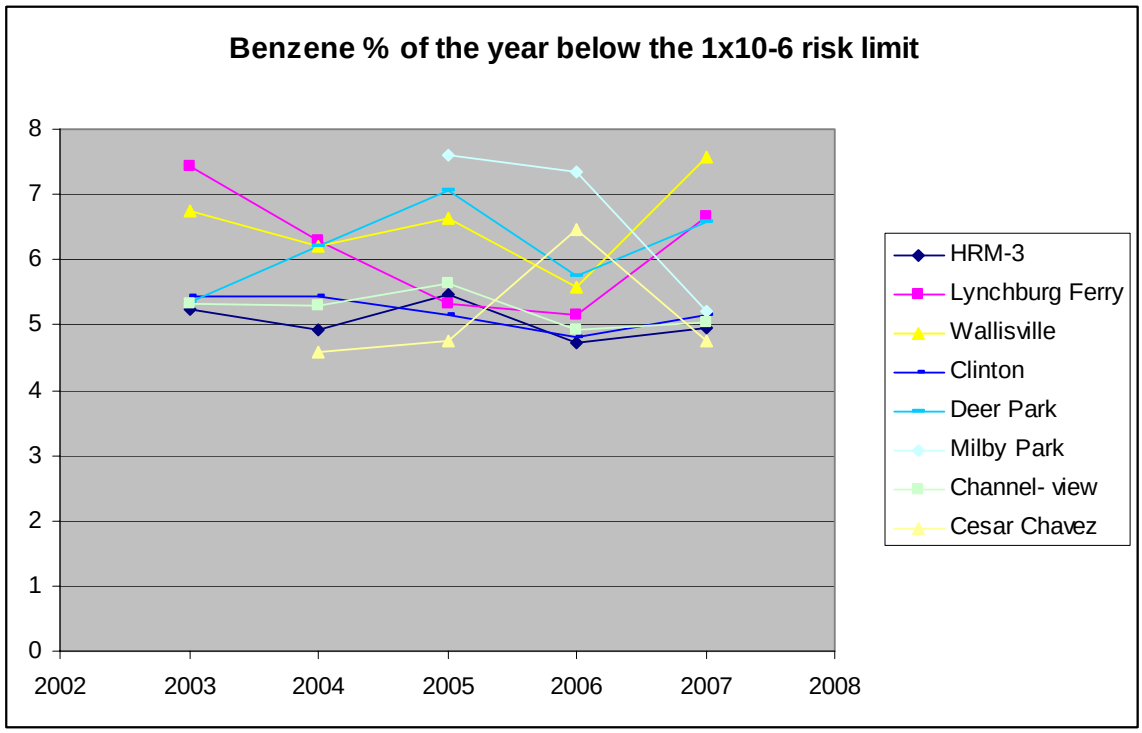
dk orange = percent of year with 50% or greater extreme values

lt orange = percent of year with 30% or greater extreme values

blank cells indicate no data were reported for the time frame

Figure H-1. Benzene % of the year below $1x10^{-6}$ risk limit


Benzene % of the year below the 1x10-6 risk limit
45
40
35
30
25
20
15
10
5
0
2002
2003
2004
2005
2006
2007
2008
HRM-3
Lynchburg Ferry
Wallisville
Tx City 34th St
Lake Jackson
Mustang Bayou
Danciger
Clinton
Deer Park
Milby Park
Channel- view
Cesar Chavez


Benzene % of the year below the 1x10-6 risk limit
8
7
6
5
4
3
2
1
0
2002
2003
2004
2005
2006
2007
2008
HRM-3
Lynchburg Ferry
Wallisville
Clinton
Deer Park
Milby Park
Channel- view
Cesar Chavez

Benzene % of the year below the $1x10^{-6}$ risk limit

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				6		5	5	5	5	5
Lynchburg Ferry						7	6	5	5	7
Wallisville						7	6	7	6	8
Tx City 34th St						6	8	8	9	21
Lake Jackson						23	42	22	25	23
Mustang Bayou						13	12	14	12	15
Danciger						12	15	12	13	19
Clinton	5	5	5	5	5	5	5	5	5	5
Deer Park	7	5	6	5	5	5	6	7	6	7
Milby Park								8	7	5
Channel-view				0	10	5	5	6	5	5
Cesar Chavez							5	5	6	5

This statistic is the percent of the year that hourly concentrations are below the $1x10^{-6}$ risk limit. This is an indicator of how often accetable values were experienced.

dk orange = percent of year with 30% or greater acceptable values

lt orange = percent of year with 10% or greater acceptable values

blank cells indicate no data were reported for the time frame

Figure I-1. Descriptive statistics: 10 years of data 1998-2007

		HRM-3	Lynchburg	Wallisville	Tex City 34th	Lake Jackson	Mustang Bayou	Danciger	Clinton	Deer Park 2	Milby Park	Channelview	Cesar Chavez
		Site_22_	Site_23_	Site_24_	Site_25_	Site_26_	Site_27_	Site_28_	Site_A_	Site_H_	Site_K_	Site_R_	Site_V_
Standard Deviation	1998								1.79	1.06			
	1999								1.75	1.30			
	2000								1.40	0.64			
	2001	1.10							1.15	0.97		1.51	
	2002								0.85	0.87		0.78	
	2003	1.00	19.56	0.42	4.57	0.24	0.72	0.20	0.99	0.95		1.66	
	2004	0.97	21.02	0.29	7.07	0.38	0.61	0.17	1.63	0.82		0.95	1.04
	2005	2.17	19.35	0.34	3.38	0.22	0.49	0.19	1.05	1.11	0.88	2.61	0.73
	2006	4.12	12.62	0.38	1.25	0.24	0.58	0.22	0.61	0.86	0.65	1.07	0.82
	2007	0.82	12.59	0.29	0.50	0.18	0.54	0.12	1.16	0.96	0.55	0.96	0.65
% of Samples Below Limit	1998								4	5			
	1999								4	3			
	2000								4	3			
	2001	1							4	4		1	
	2002								4	4		4	
	2003	2	3	2	3	2	3	2	4	4		4	
	2004	4	5	4	4	4	5	4	4	4		4	3
	2005	4	4	4	4	4	4	4	4	5	4	4	4
	2006	4	4	4	4	4	4	4	4	4	4	4	4
	2007	4	4	4	4	4	4	4	4	4	4	4	4
Number of Samples	1998								7487	6653			
	1999								6384	5351			
	2000								7662	5699			
	2001	1445							5883	6549		1839	
	2002								6416	6658		3524	
	2003	4551	4433	4503	4653	3476	3485	3821	6118	6847		7303	
	2004	7683	6879	7567	7937	6788	7202	7799	7164	6917		6111	5025
	2005	6736	7297	6403	7742	6985	7332	7375	7197	6387	6294	6311	7711
	2006	8020	7726	6346	7607	7565	7518	7227	7706	7216	7550	7371	7361
	2007	7657	7895	7655	7632	7890	7484	7694	7546	7656	7740	7494	7860
Coefficient of Variation	1998								2.61	1.66			
	1999								2.45	1.74			
	2000								1.77	1.38			
	2001	0.99							1.77	1.84		1.76	
	2002								1.50	1.39		1.18	
	2003	1.36	6.89	1.33	4.40	1.40	1.62	1.11	1.74	1.65		1.77	
	2004	1.51	9.43	1.24	4.56	2.53	1.64	1.08	2.55	1.82		1.67	1.63
	2005	3.39	6.41	1.41	4.57	1.22	1.49	1.10	1.84	2.04	1.88	3.68	1.30
	2006	7.05	5.56	1.33	3.21	1.64	1.84	1.40	1.22	1.77	2.06	1.66	1.83
	2007	1.76	8.76	1.29	2.00	1.19	1.89	1.00	2.18	2.17	1.58	1.58	1.41
Frequency of Detect	1998								85%	76%			
	1999								73%	61%			
	2000								87%	65%			
	2001	16%							67%	75%		21%	
	2002								73%	76%		40%	
	2003	52%	51%	51%	53%	40%	40%	44%	70%	78%		83%	
	2004	87%	78%	86%	90%	77%	82%	89%	82%	79%		70%	57%
	2005	77%	83%	73%	88%	80%	84%	84%	82%	73%	72%	72%	88%
	2006	92%	88%	72%	87%	86%	86%	83%	88%	82%	86%	84%	84%
	2007	87%	90%	87%	87%	90%	85%	88%	86%	87%	88%	86%	90%

		HRM-3	Lynchburg	Wallisville	Tex City 34th	Lake Jackson	Mustang Bayou	Danciger	Clinton	Deer Park 2	Milby Park	Channelview	Cesar Chavez
		Site_22_	Site_23_	Site_24_	Site_25_	Site_26_	Site_27_	Site_28_	Site_A_	Site_H_	Site_K_	Site_R_	Site_V_
95th Upper Confidence Lin	1998								0.72	0.66			
	1999								0.75	0.78			
	2000								0.82	0.47			
	2001	1.16							0.68	0.55		0.91	
	2002								0.58	0.64		0.68	
	2003	0.76	3.32	0.33	1.15	0.18	0.47	0.19	0.59	0.60		0.97	
	2004	0.66	2.65	0.24	1.68	0.16	0.38	0.16	0.67	0.46		0.59	0.66
	2005	0.68	3.39	0.25	0.80	0.18	0.34	0.18	0.59	0.57	0.49	0.76	0.57
	2006	0.66	2.51	0.29	0.41	0.15	0.32	0.16	0.52	0.50	0.33	0.66	0.46
	2007	0.48	1.67	0.23	0.26	0.15	0.30	0.13	0.56	0.46	0.36	0.63	0.48
Maximum	1998								113.68	32.56			
	1999								77.59	27.03			
	2000								52.19	13.37			
	2001	13.64							43.53	25.68		44.31	
	2002								23.82	15.63		17.75	
	2003	25.37	525.58	9.28	115.86	4.31	10.15	4.49	27.52	17.03		70.95	
	2004	31.74	1551.92	7.39	177.01	19.92	13.51	6.83	73.54	16.2		23.84	20.93
	2005	153.96	770.78	7.22	179.24	3.79	8.19	6.23	26.09	23.6	25.59	133.48	15
	2006	296.58	418.98	8.88	57.95	8.9	15.52	5.4	8.52	20.85	21.1	26.57	32.21
	2007	44.12	912.74	10.67	14.14	3.5	13.83	2.68	66.93	41.8	21.03	25.68	17.44
Mean	1998								0.69	0.64			
	1999								0.71	0.75			
	2000								0.79	0.46			
	2001	1.11							0.65	0.53		0.85	
	2002								0.57	0.63		0.66	
	2003	0.74	2.84	0.32	1.04	0.17	0.45	0.18	0.57	0.58		0.93	
	2004	0.65	2.23	0.24	1.55	0.15	0.37	0.15	0.64	0.45		0.57	0.64
	2005	0.64	3.02	0.24	0.74	0.18	0.33	0.17	0.57	0.54	0.47	0.71	0.56
	2006	0.58	2.27	0.29	0.39	0.14	0.31	0.15	0.50	0.49	0.31	0.64	0.45
	2007	0.46	1.44	0.23	0.25	0.15	0.29	0.12	0.54	0.44	0.35	0.61	0.46
Median	1998								0.41	0.38			
	1999								0.37	0.37			
	2000								0.5	0.29			
	2001	0.83							0.37	0.26		0.54	
	2002								0.31	0.37		0.49	
	2003	0.44	0.43	0.2	0.28	0.1	0.2	0.14	0.32	0.31		0.58	
	2004	0.39	0.35	0.16	0.26	0.07	0.18	0.11	0.35	0.24		0.33	0.34
	2005	0.39	0.45	0.15	0.23	0.11	0.18	0.13	0.32	0.25	0.23	0.38	0.32
	2006	0.29	0.39	0.18	0.2	0.09	0.15	0.11	0.31	0.26	0.16	0.38	0.26
	2007	0.29	0.31	0.15	0.15	0.1	0.13	0.09	0.31	0.22	0.2	0.37	0.28
Median of Lower Tail	1998								0	0.01			
	1999								0	0.015			
	2000								0.035	0			
	2001	0							0.015	0			
	2002								0.005	0.025		0.02	
	2003	0	0	0	0	0	0	0.01	0	0		0.005	
	2004	0	0	0	0	0	0	0.02	0	0		0.01	0.005
	2005	0	0	0	0	0	0	0	0	0	0	0.005	0
	2006	0.015	0	0	0	0	0.01	0.01	0	0.01	0.005	0.025	0
	2007	0	0	0	0	0	0	0.02	0.005	0	0	0	0.015
Median of Upper Tail	1998								0.77	0.7			
	1999								0.8	0.8			
	2000								0.73	0.69			
	2001	1.1							0.78	0.76		0.84	
	2002								0.78	0.73		0.68	
	2003	0.84	1.38	0.64	0.79	0.56	0.83	0.5	0.75	0.75		0.89	
	2004	0.76	1.14	0.56	0.84	0.58	0.74	0.51	0.8	0.71		0.74	0.8
	2005	0.73	1.36	0.62	0.785	0.55	0.69	0.49	0.73	0.76	0.78	0.75	0.77
	2006	0.71	1.29	0.61	0.64	0.56	0.72	0.5	0.73	0.72	0.72	0.75	0.71
	2007	0.67	1.07	0.57	0.57	0.52	0.68	0.51	0.69	0.67	0.71	0.72	0.69
Percent of Year Above 10-4 (4 ppb)	1998								1.24	1.41			
	1999								1.54	2.64			
	2000								1.51	0.60			
	2001	2.08							1.00	1.04		1.96	
	2002								0.81	1.31		0.85	
	2003	1.12	9.75	0.16	4.23	0.03	0.75	0.03	1.16	1.49		2.19	
	2004	0.99	8.48	0.05	5.57	0.09	0.29	0.01	1.06	0.81		0.82	1.17
	2005	0.95	12.24	0.06	2.80	0.00	0.16	0.03	0.96	1.63	0.94	1.09	0.66
	2006	0.66	9.94	0.13	0.70	0.04	0.40	0.11	0.48	0.91	0.40	1.13	0.53
	2007	0.37	5.71	0.05	0.29	0.00	0.28	0.00	0.72	1.02	0.22	1.04	0.19
Percent of Year Above 10-5 (.4 ppb)	1998								50.29	47.00			
	1999								46.51	46.37			
	2000								61.08	33.76			
	2001	77.09							47.03	34.66		61.39	
	2002								38.58	45.21		61.49	
	2003	53.90	51.25	21.79	37.65	10.56	28.84	7.88	39.60	38.59		64.54	
	2004	48.89	45.52	13.47	33.74	8.52	25.08	5.76	44.05	29.49		41.04	43.44
	2005	48.13	53.27	13.60	30.35	10.64	24.20	7.40	40.36	32.19	29.92	47.31	41.05
	2006	36.87	48.99	17.87	24.27	6.35	19.82	4.55	39.29	31.68	18.13	46.59	30.34
	2007	36.40	41.96	13.76	15.45	6.97	18.56	2.90	37.33	28.37	22.61	45.93	34.21
Percent of Year Below 10-6 (0.04 ppb)	1998								5.18	6.51			
	1999								5.33	5.03			
	2000								4.78	5.74			
	2001	5.54							5.25	5.05		0.00	
	2002								5.08	5.08		9.62	
	2003	5.23	7.44	6.75	6.02	22.99	13.26	11.96	5.44	5.36		5.31	
	2004	4.93	6.29	6.21	7.67	42.34	12.37	14.53	5.43	6.20		5.30	4.60
	2005	5.48	5.32	6.62	7.96	22.32	13.67	12.49	5.14	7.06	7.61	5.64	4.76
	2006	4.73	5.16	5.58	9.36	24.86	12.29	13.24	4.80	5.75	7.34	4.92	6.45
	2007	4.95	6.66	7.56	20.90	22.95	14.67	18.69	5.14	6.57	5.21	5.04	4.75

Figure J-1. Mann-Kendall trend test results: 10 years of data 1998-2007

Mann Kendall Trend Test Results: Ten Years of Data 1998-2007

benzene	95th ucl	max	mean	median	median of upper tail	% of year above 10^{-4} (4 ppb)	% of year above 10^{-5} (.4 ppb)	% of year below 10^{-6} (0.04 ppb)
HRM-3								
Lynchburg								
Wallisville								
Tx City 34th								
Lake Jackson								
Mustang Bayou								
Danciger								
Clinton	-27	-21	-27	-28	-18	-29	-27	-3
Deer Park 2	-23	1	-23	-29	-8	-5	-31	19
Milby								
Channelview								
Cesar Chavez								

S= or >19 or S<-19 is significant, +S= upward, -S=downward at 5% error rate

Figure K-1. Benzene Improvements: 10 years of data 1998-2007

Mann Kendall Trend Test Results: Ten Years of Data 1998-2007

benzene	mean (95th ucl)	max	mean	median	median of upper tail	% of year above 10^{-4} (1.5 ppb)	% of year above 10^{-5} (0.15 ppb)	% of year below 10^{-6} (0.015 ppb)
HRM-3								
Lynchburg								
Wallisville								
Tx City 34th								
Lake Jackson								
Mustang Bayou								
Danciger								
Clinton	Improving	Improving	Improving	Improving	No change	Improving	Improving	No change
Deer Park 2	Improving	No change	Improving	Improving	No change	No change	Improving	Improving
Milby								
Channelview								
Cesar Chavez								

Figure L-1. Mann-Kendall trend test results: 7 years of data 2001-2007

Mann Kendall Trend Test S-Statistic: 7 Years of Data 2001-2007

benzene	95th ucl	max	mean	median	median of upper tail	% of year above 10^{-4} (4 ppb)	% of year above 10^{-5} (.4 ppb)	% of year below 10^{-6} (0.04 ppb)
HRM-3								
Lynchburg								
Wallisville								
Tx City 34th								
Lake Jackson								
Mustang Bayou								
Danciger								
Clinton	-9	-1	-9	-9	-13	-9	-9	-5
Deer Park 2	-11	7	-11	-10	-10	-1	-13	15
Milby								
Channelview	-9	1	-9	-10	-4	-3	-9	-3
Cesar Chavez								

S= or >12 or S<-12 is significant, +S= upward, -S=downward at 5% error rate

Figure M-1. Benzene Improvements: 7 years of data 2001-2007

Mann Kendall Trend Test S-Statistic: 7 Years of Data 2001-2007

benzene	mean (95th ucl)	max	mean	median	median of upper tail	% of year above 10^{-4} (1.5 ppb)	% of year above 10^{-5} (0.15 ppb)	% of year below 10^{-6} (0.015 ppb)
HRM-3								
Lynchburg								
Wallisville								
Tx City 34th								
Lake Jackson								
Mustang Bayou								
Danciger								
Clinton	No change	No change	No change	No change	Improving	No change	No change	No change
Deer Park 2	No change	No change	No change	No change	No change	No change	Improving	Improving
Milby								
Channelview	No change	No change	No change	No change	No change	No change	No change	No change
Cesar Chavez								

Improving:	statistically signifcant improvement in air quality
Worsening:	statistically significant degradation of air quality
No Change:	no statistically significant change in air quality

5% Type I error rate

Figure N-1. Mann-Kendall trend test results: 5 years of data 2003-2007

5 years of data			S= or >7 or S<-7 is significant, +S= upward, -S=downward					
benzene	95th ucl	max	mean	median	median of upper tail	% of year above 10^{-4} (4 ppb)	% of year above 10^{-5} (.4 ppb)	% of year below 10^{-6} (0.04 ppb)
HRM-3	-8	6	-10	-8	-10	-10	-10	-2
Lynchburg	-6	0	-4	-4	-6	-2	-4	-4
Wallisville	-4	2	-4	-5	-4	-4	0	0
Tx City 34th	-8	-4	-8	-10	-8	-8	-10	10
Lake Jackson	-4	-4	-2	1	-5	-3	-4	-2
Mustang Bayou	-10	4	-10	-9	-8	-4	-10	2
Danciger	-6	-4	-6	-7	2	0	-8	6
Clinton	-4	-2	-4	-6	-7	-8	-6	-6
Deer Park 2	-6	6	-6	-4	-4	0	-6	4
Milby								
Channelview	-4	-2	-4	-3	-5	-2	-4	-4
Cesar Chavez								

Figure O-1. Benzene Improvements: 5 years of data 2003-2007

Mann Kendall Trend Test Results: 5 Years of Data 2003-2007

benzene	mean (95th ucl)	max	mean	median	median of upper tail	% of year above 10^{-4}	% of year above 10^{-5}	% of year below 10^{-6}
HRM-3	Improving	No change	Improving	Improving	Improving	Improving	Improving	No change
Lynchburg	No change	No change	No change	No change	No change	No change	No change	No change
Wallisville	No change	No change	No change	No change	No change	No change	No change	No change
Tx City 34th	Improving	No change	Improving	Improving	Improving	Improving	Improving	Improving
Lake Jackson	No change	No change	No change	No change	No change	No change	No change	No change
Mustang Bayou	Improving	No change	Improving	Improving	Improving	No change	Improving	No change
Danciger	No change	No change	No change	Improving	No change	No change	Improving	No change
Clinton	No change	No change	No change	No change	Improving	Improving	No change	No change
Deer Park 2	No change	No change	No change	No change	No change	No change	No change	No change
Milby								
Channelview	No change	No change	No change	No change	No change	No change	No change	No change
Cesar Chavez								

Improving:	statistically signifcant improvement in air quality
Worsening:	statistically significant degradation of air quality
No Change:	no statistically significant change in air quality

5% Type I error rate

Figure P-1. Average statistical ranks

2007	Mean at 95% upper conf		max		median		median of upper tail		% of year above 10^{-4} (4		% of year above 10^{-5} (.4		percent of year below 10^{-6} (0.04		average rank
Benzene	ppb	rank	ppb	rank	ppb	rank	ppb	rank	%	rank	%	rank	%	rank	
HRM-3	0.48	9	44.12	10	0.29	9	0.67	5	0.37	8	36.40	9	4.95	11	8.7
Lynchburg	1.67	12	912.74	12	0.31	10	1.07	12	5.71	12	41.96	11	6.66	6	10.7
Wallisville	0.23	3	10.67	3	0.15	4	0.57	3	0.05	3	13.76	3	7.56	5	3.4
Tx City 34th	0.26	4	14.14	5	0.15	4	0.57	3	0.29	7	15.45	4	20.90	2	4.1
Lake Jackson	0.15	2	3.50	2	0.1	2	0.52	2	0.00	1	6.97	2	22.95	1	1.7
Mustang Bayou	0.30	5	13.83	4	0.13	3	0.68	7	0.28	6	18.56	5	14.67	4	4.9
Danciger	0.13	1	2.68	1	0.09	1	0.51	1	0.00	1	2.90	1	18.69	3	1.3
Clinton	0.56	10	66.93	11	0.31	10	0.69	8	0.72	9	37.33	10	5.14	9	9.6
Deer Park 2	0.46	7	41.80	9	0.22	7	0.67	5	1.02	10	28.37	7	6.57	7	7.4
Milby	0.36	6	21.03	7	0.2	6	0.71	10	0.22	5	22.61	6	5.21	8	6.9
Channelview	0.63	11	25.68	8	0.37	12	0.72	11	1.04	11	45.93	12	5.04	10	10.7
Cesar Chavez	0.48	8	17.44	6	0.28	8	0.69	8	0.19	4	34.21	8	4.75	12	7.7

concentrations in ppbV
rank is the rank order of the statistic
high ranks correspond to higher concentrations or higher precentages with the following exception
in the category of "percent of year below 10^{-6}", high ranks correspond to lower precentages

Figure Q-1. Benzene % of samples below detection limit

Benzene Percent of Samples Below Limit

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				1		2	4	4	4	4
Lynchburg Ferry						3	5	4	4	4
Wallisville						2	4	4	4	4
Tx City 34th St						3	4	4	4	4
Lake Jackson						2	4	4	4	4
Mustang Bayou						3	5	4	4	4
Danciger						2	4	4	4	4
Clinton	4	4	4	4	4	4	4	4	4	4
Deer Park	5	3	3	4	4	4	4	5	4	4
Milby Park								4	4	4
Channel-view				1	4	4	4	4	4	4
Cesar Chavez							3	4	4	4

This statistic is the number of samples where the concentration was below the detection limit. These samples were replaced with 1/2 the detection limit for statistical calculations.

Figure R-1. Benzene frequency of detection

Benzene Frequency of Detect

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				16%		52%	87%	77%	92%	87%
Lynchburg Ferry						51%	78%	83%	88%	90%
Wallisville						51%	86%	73%	72%	87%
Tx City 34th St						53%	90%	88%	87%	87%
Lake Jackson						40%	77%	80%	86%	90%
Mustang Bayou						40%	82%	84%	86%	85%
Danciger						44%	89%	84%	83%	88%
Clinton	85%	73%	87%	67%	73%	70%	82%	82%	88%	86%
Deer Park	76%	61%	65%	75%	76%	78%	79%	73%	82%	87%
Milby Park								72%	86%	88%
Channel-view				21%	40%	83%	70%	72%	84%	86%
Cesar Chavez							57%	88%	84%	90%

This statistic is the number of samples where a concentration was detected out of the total number of samples available.

Figure S-1. Benzene number of samples

Benzene Number of Samples

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				1445		4551	7683	6736	8020	7657
Lynchburg Ferry						4433	6879	7297	7726	7895
Wallisville						4503	7567	6403	6346	7655
Tx City 34th St						4653	7937	7742	7607	7632
Lake Jackson						3476	6788	6985	7565	7890
Mustang Bayou						3485	7202	7332	7518	7484
Danciger						3821	7799	7375	7227	7694
Clinton	7487	6384	7662	5883	6416	6118	7164	7197	7706	7546
Deer Park	6653	5351	5699	6549	6658	6847	6917	6387	7216	7656
Milby Park								6294	7550	7740
Channel-view				1839	3524	7303	6111	6311	7371	7494
Cesar Chavez							5025	7711	7361	7860

Figure T-1. Benzene coefficient of variation

Benzene Coefficient of Variation

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				0.99		1.36	1.51	3.39	7.05	1.76
Lynchburg Ferry						6.89	9.43	6.41	5.56	8.76
Wallisville						1.33	1.24	1.41	1.33	1.29
Tx City 34th St						4.40	4.56	4.57	3.21	2.00
Lake Jackson						1.40	2.53	1.22	1.64	1.19
Mustang Bayou						1.62	1.64	1.49	1.84	1.89
Danciger						1.11	1.08	1.10	1.40	1.00
Clinton	2.61	2.45	1.77	1.77	1.50	1.74	2.55	1.84	1.22	2.18
Deer Park	1.66	1.74	1.38	1.84	1.39	1.65	1.82	2.04	1.77	2.17
Milby Park								1.88	2.06	1.58
Channel-view				1.76	1.18	1.77	1.67	3.68	1.66	1.58
Cesar Chavez							1.63	1.30	1.83	1.41

This statistic may indicate non-normality if it exceeds 1.2.

Figure A-2. 1,3-Butadiene mean with 95% confidence

1,3-Butadiene Mean (with 95% Confidence) ppbV

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				0.50		0.50	0.44	0.37	0.21	0.18
Lynchburg Ferry						0.59	0.44	0.37	0.19	0.15
Wallisville						0.15	0.17	0.10	0.07	0.08
Tx City 34th St						0.11	0.13	0.09	0.04	0.06
Lake Jackson						0.05	0.06	0.07	0.04	0.04
Mustang Bayou						0.14	0.12	0.10	0.07	0.08
Danciger						0.05	0.05	0.04	0.04	0.03
Clinton	1.19	0.60	0.64	0.36	0.41	0.39	0.62	0.32	0.30	0.23
Deer Park	0.30	0.25	0.16	0.16	0.17	0.30	0.22	0.20	0.24	0.22
Milby Park								1.53	1.65	1.03
Channel- view				0.53	0.48	0.54	0.40	0.46	0.38	0.26
Cesar Chavez							0.56	0.46	0.26	0.24

This statistic is the upper 95th confidence limit of the annual mean of the hourly automatic gas chromatograph data. Although the true mean cannot be known without analyzing all of the air, the probability that the true mean is higher than this number is held to 5%.

red =$1x10^{-4}$ risk, 1.5 ppbV, or greater

orange =$1x10^{-5}$ risk, 0.15 ppbV, or greater

yellow = $1x10^{-6}$ risk, 0.015 ppbV rounded to 0.02 ppbV, or greater

green =less than $1x10^{-6}$ risk

blank cells indicate no data were reported for the time frame

Figure B-2. 1,3-Butadiene maximum

1,3-Butadiene Maximum ppbV

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				16.31		39.67	57.13	84.72	89.29	10.91
Lynchburg Ferry						43.54	55.77	121.87	17.11	20.11
Wallisville						7.95	14.67	8.99	24.33	27.5
Tx City 34th St						41.66	26.07	49.01	5.79	9.13
Lake Jackson						4.13	2.27	3.89	4.54	4.55
Mustang Bayou						38.12	33.29	38.74	29.25	47.97
Danciger						6.88	1.3	2.23	2.27	8.57
Clinton	112.24	35.79	48.82	24.41	23.41	15.92	35.54	54.98	116.92	25.72
Deer Park	45.52	12.89	8.33	43.1	18.67	72.24	23.39	8.05	11.28	203.4
Milby Park								82.25	1611.25	73.93
Channel-view				79.26	49.53	36.04	24.36	54.47	53.23	32.89
Cesar Chavez							37.02	52.47	53.96	31.08

This statistic is the maximum concentration of the 1 hour annual data.

red =$1x10^{-4}$ risk, 1.5 ppbV, or greater

orange =$1x10^{-5}$ risk, 0.15 ppbV, or greater

yellow = $1x10^{-6}$ risk, 0.015 ppbV rounded to 0.02 ppbV, or greater

green =less than $1x10^{-6}$ risk

blank cells indicate no data were reported for the time frame

Figure C-2. 1,3-Butadiene mean

1,3-Butadiene Mean ppbV

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				0.46		0.46	0.42	0.34	0.19	0.18
Lynchburg Ferry						0.55	0.41	0.34	0.18	0.14
Wallisville						0.14	0.16	0.09	0.06	0.07
Tx City 34th St						0.10	0.12	0.07	0.04	0.06
Lake Jackson						0.04	0.05	0.06	0.03	0.04
Mustang Bayou						0.10	0.11	0.09	0.06	0.07
Danciger						0.05	0.05	0.04	0.03	0.03
Clinton	1.10	0.56	0.60	0.34	0.38	0.36	0.58	0.30	0.27	0.22
Deer Park	0.28	0.24	0.15	0.14	0.16	0.25	0.21	0.19	0.24	0.17
Milby Park								1.45	1.24	1.00
Channel- view				0.43	0.45	0.50	0.37	0.42	0.35	0.24
Cesar Chavez							0.52	0.43	0.24	0.23

This statistic is the the annual sample mean of the hourly automatic gas chromatograph data without confidence. It is used in conjunction with the number of samples collected and the standard deviation of the samples to calculate the upper confidence limit of the true mean.

red =$1x10^{-4}$ risk, 1.5 ppbV, or greater

orange =$1x10^{-5}$ risk, 0.15 ppbV, or greater

yellow = $1x10^{-6}$ risk, 0.015 ppbV rounded to 0.02 ppbV, or greater

green =less than $1x10^{-6}$ risk

blank cells indicate no data were reported for the time frame

Figure D-2. 1,3-Butadiene median

1,3-Butadiene Median ppbV

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				0.2		0.13	0.12	0.11	0.08	0.08
Lynchburg Ferry						0.24	0.15	0.1	0.08	0.06
Wallisville						0.06	0.1	0.05	0.03	0.03
Tx City 34th St						0.03	0.05	0.02	0.02	0.03
Lake Jackson						0.03	0.04	0.03	0.02	0.02
Mustang Bayou						0.01	0.02	0.02	0	0.02
Danciger						0.02	0.03	0.02	0.02	0.02
Clinton	0.18	0.16	0.1	0.13	0.11	0.11	0.14	0.11	0.11	0.1
Deer Park	0.08	0.08	0.04	0.03	0.05	0.05	0.08	0.08	0.17	0.07
Milby Park								0.19	0.14	0.22
Channel- view				0.1	0.08	0.12	0.07	0.06	0.08	0.04
Cesar Chavez							0.08	0.12	0.08	0.09

This statistic is the middle 50% of the data. It is a better indicator of central tendancy of the data distribution than the mean for skewed environmental datasets.

red =$1x10^{-4}$ risk, 1.5 ppbV, or greater

orange =$1x10^{-5}$ risk, 0.15 ppbV, or greater

yellow = $1x10^{-6}$ risk, 0.015 ppbV rounded to 0.02 ppbV, or greater

green =less than $1x10^{-6}$ risk

blank cells indicate no data were reported for the time frame

Figure E-2. 1,3-Butadiene median of concentrations above 1 x 10^{-5} risk

1,3-Butadiene Median of Concentrations above 1x10^{-5} risk ppbV

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				0.40		0.38	0.37	0.35	0.29	0.28
Lynchburg Ferry						0.28	0.28	0.31	0.29	0.28
Wallisville						0.31	0.24	0.27	0.26	0.26
Tx City 34th St						0.25	0.25	0.26	0.24	0.23
Lake Jackson						0.23	0.23	0.24	0.22	0.22
Mustang Bayou						0.34	0.32	0.30	0.29	0.28
Danciger						0.26	0.24	0.23	0.23	0.23
Clinton	0.48	0.42	0.47	0.37	0.45	0.36	0.44	0.34	0.33	0.32
Deer Park	0.36	0.36	0.33	0.31	0.30	0.39	0.31	0.31	0.26	0.30
Milby Park								0.97	0.65	0.85
Channel- view				0.38	0.43	0.47	0.48	0.41	0.34	0.36
Cesar Chavez							0.47	0.43	0.35	0.35

This statistic is the middle 50% of the data which exceeds the 1x10^{-5} risk limit. It is an indicator of the severity to which the concentrations exceed the limit.

pink = concentrations are 3x the 1x10^{-5} risk, 0.45 ppbV, or greater

rose = concentrations are 2x the 1x10^{-5} risk, 0.3 ppbV, or greater

blank cells indicate no data were reported for the time frame

Figure F-2. 1,3-Butadiene % of the year that exceeds $1x10^{-4}$ risk limit

1,3-Butadiene % of the year that exceeds the $1x10^{-4}$ risk limit

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				5		6	5	3	1	1
Lynchburg Ferry						6	4	3	1	1
Wallisville						1	1	0	0	0
Tx City 34th St						0	1	0	0	0
Lake Jackson						0	0	0	0	0
Mustang Bayou						1	1	1	0	0
Danciger						0	0	0	0	0
Clinton	12	7	8	4	5	5	8	3	2	1
Deer Park	3	3	1	1	1	3	2	2	1	1
Milby Park								22	13	19
Channel- view				4	6	7	6	5	4	3
Cesar Chavez							8	5	2	2

This statistic is the percent of the year that hourly concentrations exceeded the $1x10^{-4}$ risk limit. This is an indicator of how often very extreme values were experienced.

dk gray = percent of year with 10% or greater extreme values

lt gray = percent of year with 5% or greater extreme values

Figure G-2. 1,3-Butadiene % of the year that exceeds $1x10^{-5}$ risk limit

1,3-Butadiene % of the year that exceeds the $1x10^{-5}$ risk limit

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				57		44	43	38	27	28
Lynchburg Ferry						80	47	33	22	21
Wallisville						19	28	11	8	9
Tx City 34th St						10	11	7	3	6
Lake Jackson						5	6	7	2	3
Mustang Bayou						10	13	10	8	7
Danciger						5	3	4	3	2
Clinton	54	51	39	44	41	41	46	38	40	35
Deer Park	31	29	21	19	23	21	26	27	54	23
Milby Park								53	49	55
Channel- view				39	36	43	32	31	33	21
Cesar Chavez							36	43	32	35

This statistic is the percent of the year that hourly concentrations exceeded the $1x10^{-4}$ risk limit. This is an indicator of how often extreme values were experienced.

dk orange = percent of year with 50% or greater extreme values

lt orange = percent of year with 30% or greater extreme values

blank cells indicate no data were reported for the time frame

Figure H-2. 1,3-Butadiene % of the year below $1x10^{-6}$ risk limit

1,3-Butadiene % of the year below the $1x10^{-6}$ risk limit

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				6		7	6	8	5	4
Lynchburg Ferry						6	7	7	5	11
Wallisville						7	6	6	32	21
Tx City 34th St						25	6	34	28	12
Lake Jackson						35	40	33	38	34
Mustang Bayou						58	45	48	57	49
Danciger						33	10	41	36	32
Clinton	9	5	7	6	9	10	5	6	5	6
Deer Park	12	19	36	46	21	18	6	7	5	5
Milby Park								13	7	8
Channel- view				9	11	8	13	27	12	24
Cesar Chavez							6	6	23	19

This statistic is the percent of the year that hourly concentrations are below the $1x10^{-6}$ risk limit. This is an indicator of how often accetable values were experienced.

dk orange = percent of year with 30% or greater acceptable values

lt orange = percent of year with 10% or greater acceptable values

blank cells indicate no data were reported for the time frame

Figure I-2. Descriptive statistics: 10 years of data 1998-2007

		HRM-3	Lynchburg	Wallisville	Tx City 34th	Lake Jackson	Mustang Bayou	Danciger	Clinton	Deer Park 2	Milby	Channelview	Cesar Chavez	Aldine	HRM-7	Bayland
		22	23	24	25	26	27	28	a	h	k	r	v	q	s	m
95th Upper Confidence Lin	1998								1.19	0.30						0.16
	1999								0.60	0.25						0.13
	2000								0.64	0.16				0.18		0.09
	2001	0.50							0.36	0.16		0.53		0.16	4.33	
	2002								0.41	0.17		0.48				
	2003	0.50	0.59	0.15	0.11	0.05	0.14	0.05	0.39	0.30		0.54				
	2004	0.44	0.44	0.17	0.13	0.06	0.12	0.05	0.62	0.22		0.40	0.56			
	2005	0.37	0.37	0.10	0.09	0.07	0.10	0.04	0.32	0.20	1.53	0.46	0.46			
	2006	0.21	0.19	0.07	0.04	0.04	0.07	0.04	0.30	0.24	1.65	0.38	0.26			
	2007	0.18	0.15	0.08	0.06	0.04	0.08	0.03	0.23	0.22	1.03	0.26	0.24			
Maximum	1998								112.24	45.52						7.38
	1999								35.79	12.89						4.5
	2000								48.82	8.33				2.7		4.89
	2001	16.31							24.41	43.1		79.26		4.96	87.58	
	2002								23.41	18.67		49.53				
	2003	39.67	43.54	7.95	41.66	4.13	38.12	6.88	15.92	72.24		36.04				
	2004	57.13	55.77	14.67	26.07	2.27	33.29	1.3	35.54	23.39		24.36	37.02			
	2005	84.72	121.87	8.99	49.01	3.89	38.74	2.23	54.98	8.05	82.25	54.47	52.47			
	2006	89.29	17.11	24.33	5.79	4.54	29.25	2.27	116.92	11.28	1611.25	53.23	53.96			
	2007	10.91	20.11	27.5	9.13	4.55	47.97	8.57	25.72	203.4	73.93	32.89	31.08			
Mean	1998								1.10	0.28						0.16
	1999								0.56	0.24						0.13
	2000								0.60	0.15				0.16		0.09
	2001	0.46							0.34	0.14		0.43		0.16	3.84	
	2002								0.38	0.16		0.45				
	2003	0.46	0.55	0.14	0.10	0.04	0.10	0.05	0.36	0.25		0.50				
	2004	0.42	0.41	0.16	0.12	0.05	0.11	0.05	0.58	0.21		0.37	0.52			
	2005	0.34	0.34	0.09	0.07	0.06	0.09	0.04	0.30	0.19	1.45	0.42	0.43			
	2006	0.19	0.18	0.06	0.04	0.03	0.06	0.03	0.27	0.24	1.24	0.35	0.24			
	2007	0.18	0.14	0.07	0.06	0.04	0.07	0.03	0.22	0.17	1.00	0.24	0.23			
Median	1998								0.18	0.08						0.07
	1999								0.16	0.08						0.06
	2000								0.10	0.04				0.07		0.03
	2001	0.20							0.13	0.03		0.10		0.07	0.57	
	2002								0.11	0.05		0.08				
	2003	0.13	0.24	0.06	0.03	0.03	0.01	0.02	0.11	0.05		0.12				
	2004	0.12	0.15	0.10	0.05	0.04	0.02	0.03	0.14	0.08		0.07	0.08			
	2005	0.11	0.10	0.05	0.02	0.03	0.02	0.02	0.11	0.08	0.19	0.06	0.12			
	2006	0.08	0.08	0.03	0.02	0.02	0.00	0.02	0.11	0.17	0.14	0.08	0.08			
	2007	0.08	0.06	0.03	0.03	0.02	0.02	0.02	0.10	0.07	0.22	0.04	0.09			
Median of Lower Tail	1998								0.00	0.00						0.00
	1999								0.00	0.00						0.00
	2000								0.00	0.00				0.00		0.00
	2001	0.00							0.00	0.00		0.00		0.01	0.00	
	2002								0.00	0.00		0.00				
	2003	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00		0.00				
	2004	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00			
	2005	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
	2006	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
	2007	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
Median of Upper Tail	1998								0.48	0.36						0.31
	1999								0.42	0.36						0.30
	2000								0.47	0.33				0.32		0.29
	2001	0.40							0.37	0.31		0.38		0.31	1.87	
	2002								0.45	0.30		0.43				
	2003	0.38	0.28	0.31	0.25	0.23	0.34	0.26	0.36	0.39		0.47				
	2004	0.37	0.28	0.24	0.25	0.23	0.32	0.24	0.44	0.31		0.48	0.47			
	2005	0.35	0.31	0.27	0.26	0.24	0.30	0.23	0.34	0.31	0.97	0.41	0.43			
	2006	0.29	0.29	0.26	0.24	0.22	0.29	0.23	0.33	0.26	0.65	0.34	0.35			
	2007	0.28	0.28	0.26	0.23	0.22	0.28	0.23	0.32	0.30	0.85	0.36	0.35			
Percent of Year Above 10-4 (4 ppb)	1998								11.53	3.30						0.86
	1999								7.33	2.97						0.44
	2000								7.90	1.32				0.71		0.60
	2001	5.31							4.02	1.06		3.57		0.47	35.95	
	2002								5.28	1.15		6.45				
	2003	5.65	6.36	1.11	0.47	0.05	0.59	0.05	4.88	2.63		7.09				
	2004	5.29	3.99	0.55	0.60	0.01	1.09	0.00	7.88	2.00		5.82	7.64			
	2005	3.05	3.27	0.37	0.33	0.11	0.58	0.01	3.01	1.59	21.64	5.29	5.46			
	2006	0.85	1.44	0.20	0.16	0.08	0.33	0.04	1.77	0.64	13.24	3.78	2.25			
	2007	1.00	0.69	0.22	0.05	0.05	0.36	0.04	1.31	0.72	19.23	3.33	1.85			
Percent of Year Above 10-5 (.4 ppb)	1998								53.88	30.74						22.87
	1999								51.05	29.16						19.63
	2000								38.71	21.07				28.50		12.11
	2001	56.62							44.25	19.47		39.44		27.92	65.25	
	2002								40.63	22.93		35.78				
	2003	44.04	79.61	18.88	10.21	5.19	9.56	5.19	41.13	21.16		43.45				
	2004	43.26	47.31	27.88	11.12	5.92	12.93	3.02	46.49	25.51		31.62	36.13			
	2005	38.16	32.87	10.71	6.64	7.28	10.37	4.37	38.49	27.45	53.33	30.87	43.04			
	2006	27.31	22.49	7.57	3.09	2.11	8.15	2.70	40.23	54.49	48.53	32.52	32.14			
	2007	28.32	20.81	8.99	5.59	3.11	7.18	2.43	34.72	23.45	55.32	20.99	35.03			
Percent of Year Below 10-6 (0.04 ppb)	1998								9.41	11.55						6.05
	1999								5.24	18.64						9.40
	2000								6.99	36.37				12.21		36.22
	2001	6.39							5.92	46.01		8.89		13.24	10.35	
	2002								9.06	20.98		10.64				
	2003	6.69	5.53	6.97	24.87	34.66	58.25	32.79	9.58	17.63		7.73				
	2004	6.14	6.56	6.22	6.50	40.14	45.28	10.15	5.23	6.43		13.38	6.05			
	2005	7.63	6.81	6.37	34.07	32.75	47.85	41.39	6.26	6.86	12.55	26.73	5.63			
	2006	5.12	4.76	32.29	28.39	37.82	56.91	36.25	5.38	5.46	7.14	11.91	23.35			
	2007	4.00	10.54	21.50	11.93	34.46	49.26	31.72	5.87	4.94	8.23	24.47	19.11			

		HRM-3	Lynchburg	Wallisville	Tx City 34th	Lake Jackson	Mustang Bayou	Danciger	Clinton	Deer Park 2	Milby	Channelview	Cesar Chavez	Aldine	HRM-7	Bayland
		22	23	24	25	26	27	28	a	h	k	r	v	q	s	m
Standard Deviation	1998								4.74	1.02						0.32
	1999								1.63	0.59						0.23
	2000								2.03	0.41				0.27		0.24
	2001	1.01							0.82	0.83		2.74		0.26	8.93	
	2002								1.00	0.47		1.53				
	2003	1.48	1.47	0.34	0.76	0.10	1.05	0.13	0.92	1.70		1.55				
	2004	1.37	1.75	0.40	0.72	0.09	0.58	0.06	1.73	0.63		1.12	1.65			
	2005	1.59	1.85	0.28	0.75	0.13	0.62	0.08	0.99	0.38	3.58	1.99	1.54			
	2006	1.14	0.57	0.39	0.15	0.10	0.38	0.07	1.43	0.32	22.00	1.50	0.85			
	2007	0.40	0.38	0.37	0.14	0.09	0.65	0.11	0.55	2.36	2.11	1.03	0.58			
% of Samples Below Limit	1998								4.13	4.93						2.35
	1999								3.58	3.05						4.11
	2000								4.18	2.84				1.07		2.32
	2001	0.88							3.57	3.57		1.26		2.28	0.75	
	2002								3.63	3.86		3.87				
	2003	2.44	2.68	2.43	2.56	2.19	2.83	2.39	3.53	3.95		3.96				
	2004	4.25	4.63	4.84	4.36	4.38	4.53	4.32	3.98	4.26		3.70	2.63			
	2005	4.08	4.05	3.56	4.19	4.26	4.09	4.33	4.13	4.70	4.00	4.05	4.09			
	2006	4.30	4.03	3.72	4.19	4.19	4.05	4.10	4.13	4.38	4.05	4.14	4.10			
	2007	3.05	3.09	3.09	3.17	3.05	2.97	2.99	3.05	3.28	3.14	3.03	3.07			
Number of Samples	1998								7494	6509						3721
	1999								6408	5349						7285
	2000								7086	5543				1695		3526
	2001	1487							5865	6514		1879		3815	918	
	2002								4844	6162		6571				
	2003	4321	4448	4492	4660	4008	2898	4083	3749	4367		4953				
	2004	7511	6967	7617	7944	6701	7272	7883	7043	5939		4551	5024			
	2005	6727	7311	6454	7623	7032	7601	7374	6976	6047	6413	5675	7712			
	2006	8022	7689	6342	7502	7626	7524	7341	7753	7137	7573	7081	7378			
	2007	7580	7798	7563	7587	7777	7436	7663	7543	7536	7797	7021	7665			
Coefficient of Variation	1998								4.31	3.62						2.02
	1999								2.89	2.49						1.79
	2000								3.39	2.76				1.61		2.70
	2001	2.18							2.40	5.79		6.42		1.63	2.32	
	2002								2.61	3.00		3.42				
	2003	3.23	2.66	2.39	7.96	2.28	10.05	2.93	2.56	6.72		3.08				
	2004	3.28	4.29	2.51	6.22	1.69	5.26	1.23	2.97	2.99		3.00	3.16			
	2005	4.74	5.48	2.94	10.22	1.96	6.97	2.14	3.28	1.98	2.46	4.72	3.60			
	2006	6.14	3.16	6.01	3.71	3.09	6.31	2.06	5.22	1.36	17.80	4.28	3.53			
	2007	2.26	2.76	5.13	2.62	2.47	9.34	3.52	2.51	13.63	2.12	4.31	2.47			
Frequency of Detect	1998								86%	74%						42%
	1999								73%	61%						83%
	2000								81%	63%				19%		40%
	2001	17%							67%	74%		21%		44%	10%	
	2002								55%	70%		75%				
	2003	49%	51%	51%	53%	46%	33%	47%	43%	50%		57%				
	2004	86%	79%	87%	90%	76%	83%	90%	80%	68%		52%	57%			
	2005	77%	83%	74%	87%	80%	87%	84%	80%	69%	73%	65%	88%			
	2006	92%	88%	72%	86%	87%	86%	84%	89%	81%	86%	81%	84%			
	2007	87%	89%	86%	87%	89%	85%	87%	86%	86%	89%	80%	88%			

Figure J-2. Mann-Kendall trend test results: 10 years of data 1998-2007

Mann Kendall Trend Test Results: Ten Years of Data 1998-2007

1,3 butadiene	mean (95th ucl)	max	mean	median	median of upper tail	% of year above 10^{-4} (1.5 ppb)	% of year above 10^{-5} (0.15 ppb)	% of year below 10^{-6} (0.015 ppb)
HRM-3								
Lynchburg								
Wallisville								
Tx City 34th								
Lake Jackson								
Mustang Bayou								
Danciger								
Clinton	-31	-3	-31	-20	-33	-31	-25	-9
Deer Park 2	-1	1	-5	10	-24	-23	5	-25
Milby								
Channelview								
Cesar Chavez								
Aldine								
HRM-7								
Bayland								

S= or >19 or S<-19 is significant, +S= upward, -S=downward at 5% error rate

Figure K-2. 1,3-Butadiene Improvements: 10 years of data 1998-2007

Mann Kendall Trend Test Results: Ten Years of Data 1998-2007

1,3 butadiene	mean (95th ucl)	max	mean	median	median of upper tail	% of year above 10^{-4}	% of year above 10^{-5}	% of year below 10^{-6}
HRM-3								
Lynchburg								
Wallisville								
Tx City 34th								
Lake Jackson								
Mustang Bayou								
Danciger								
Clinton	Improving	No change	Improving	Improving	Improving	Improving	Improving	No change
Deer Park 2	No change	No change	No change	No change	Improving	Improving	No change	Worsening
Milby								
Channelview								
Cesar Chavez								
Aldine								
HRM-7								
Bayland								

Improving: statistically signifcant improvement in air quality

Worsening: statistically significant degradation of air quality

No Change: no statistically significant change in air quality

5% Type I error rate

Figure L-2. Mann-Kendall trend test results: 7 years of data 2001-2007

Mann Kendall Trend Test Results: 7 Years of Data 2001-2007

1,3 butadiene	mean (95th ucl)	max	mean	median	median of upper tail	% of year above 10^{-4} (1.5 ppb)	% of year above 10^{-5} (0.15 ppb)	% of year below 10^{-6} (0.015 ppb)
HRM-3								
Lynchburg								
Wallisville								
Tx City 34th								
Lake Jackson								
Mustang Bayou								
Danciger								
Clinton	-11	9	-11	-9	-15	-11	-11	-5
Deer Park 2	7	-1	5	13	-7	-5	13	-19
Milby								
Channelview	-15	-7	-13	-12	-5	-9	-13	11
Cesar Chavez								
Aldine								
HRM-7								
Bayland								

S= or >12 or S<-12 is significant, +S= upward, -S=downward at 5% error rate

Figure M-2. 1,3-Butadiene Improvements: 7 years of data 2001-2007

Mann Kendall Trend Test S-Statistic: 7 Years of Data 2001-2007

1,3 butadiene	mean (95th ucl)	max	mean	median	median of upper tail	% of year above 10^{-4}	% of year above 10^{-5}	% of year below 10^{-6}
HRM-3								
Lynchburg								
Wallisville								
Tx City 34th								
Lake Jackson								
Mustang Bayou								
Danciger								
Clinton	No change	No change	No change	No change	Improving	No change	No change	No change
Deer Park 2	No change	No change	No change	Worsening	No change	No change	Worsening	Worsening
Milby								
Channelview	Improving	No change	Improving	Improving	No change	No change	Improving	No change
Cesar Chavez								
Aldine								
HRM-7								
Bayland								

Improving:	Improving: statistically signifcant improvement in air quality
Worsening:	Worsening: statistically significant degradation of air quality
No Change:	No Change: no statistically significant change in air quality

5% Type I error rate

Figure N-2. Mann-Kendall trend test results: 5 years of data 2003-2007

Mann Kendall Trend Test S-Statistic: 5 Years of Data 2003-2007

1,3 butadiene	mean (95th ucl)	max	mean	median	median of upper tail	% of year above 10^{-4} (1.5 ppb)	% of year above 10^{-5} (0.15 ppb)	% of year below 10^{-6} (0.015 ppb)
HRM-3	-10	2	-10	-9	-10	-8	-8	-6
Lynchburg	-10	-2	-10	-10	1	-10	-10	4
Wallisville	-6	8	-6	-7	-3	-8	-6	4
Tx City 34th	-6	-4	-6	-2	-6	-8	-6	0
Lake Jackson	-2	6	-2	-6	-3	2	-2	-2
Mustang Bayou	-8	2	-6	1	-10	-6	-6	0
Danciger	-10	4	-8	-2	-7	0	-8	0
Clinton	-8	4	-8	-5	-8	-8	-6	-2
Deer Park 2	-4	0	-6	3	-7	-8	4	-8
Milby								
Channelview	-8	0	-8	-6	-6	-10	-6	4
Cesar Chavez								
Aldine								
HRM-7								
Bayland								

S= or >7 or S<-7 is significant, +S= upward, -S=downward

Figure O-2. 1,3-Butadiene Improvements: 5 years of data 2003-2007

Mann Kendall Trend Test Results: 5 Years of Data 2003-2007

1,3 butadiene	mean (95th ucl)	max	mean	median	median of upper tail	% of year above 10^{-4}	% of year above 10^{-5}	% of year below 10^{-6}
HRM-3	Improving	No change	Improving	Improving	Improving	Improving	Improving	No change
Lynchburg	Improving	No change	Improving	Improving	No change	Improving	Improving	No change
Wallisville	No change	Worsening	No change	Improving	No change	Improving	No change	No change
Tx City 34th	No change	No change	No change	No change	No change	Improving	No change	No change
Lake Jackson	No change	No change	No change	No change	No change	No change	No change	No change
Mustang Bayou	Improving	No change	No change	No change	Improving	No change	No change	No change
Danciger	Improving	No change	Improving	No change	Improving	No change	Improving	No change
Clinton	Improving	No change	Improving	No change	Improving	Improving	No change	No change
Deer Park 2	No change	No change	No change	No change	Improving	Improving	No change	Worsening
Milby								
Channelview	Improving	No change	Improving	No change	No change	Improving	No change	No change
Cesar Chavez								
Aldine								
HRM-7								
Bayland								

Improving:	Improving: statistically signifcant improvement in air quality
Worsening:	Worsening: statistically significant degradation of air quality
No Change:	No Change: no statistically significant change in air quality

5% Type I error rate

Figure P-2. Average statistical ranks

2007	Mean at 95% upper conf		max		median		median of upper tail		% of year above 10^{-4} (1.5		% of year above 10^{-5} (.15		percent of year below 10^{-6}		average rank
1,3 butadiene	ppb	rank	ppb	rank	ppb	rank	ppb	rank	%	rank	%	rank	%	rank	
HRM-3	0.18	7	10.91	4	0.08	9	0.28	5	1.00	8	28.32	9	4.00	12	7.7
Lynchburg	0.15	6	20.11	5	0.06	7	0.28	5	0.69	6	20.81	6	10.54	8	6.1
Wallisville	0.08	4	27.5	7	0.03	4	0.26	4	0.22	4	8.99	5	21.50	5	4.7
Tx City 34th	0.06	3	9.13	3	0.03	4	0.23	2	0.05	3	5.59	3	11.93	7	3.6
Lake Jackson	0.04	2	4.55	1	0.02	1	0.22	1	0.05	2	3.11	2	34.46	2	1.6
Mustang Bayou	0.08	5	47.97	10	0.02	1	0.28	5	0.36	5	7.18	4	49.26	1	4.4
Danciger	0.03	1	8.57	2	0.02	1	0.23	2	0.04	1	2.43	1	31.72	3	1.6
Clinton	0.23	9	25.72	6	0.1	11	0.32	9	1.31	9	34.72	10	5.87	10	9.1
Deer Park 2	0.22	8	203.4	12	0.07	8	0.3	8	0.72	7	23.45	8	4.94	11	8.9
Milby	1.03	12	73.93	11	0.22	12	0.85	12	19.23	12	55.32	12	8.23	9	11.4
Channelview	0.26	11	32.89	9	0.04	6	0.36	11	3.33	11	20.99	7	24.47	4	8.4
Cesar Chavez	0.24	10	31.08	8	0.09	10	0.35	10	1.85	10	35.03	11	19.11	6	9.3

concentrations in ppbV
rank is the rank order of the statistic
high ranks correspond to higher concentrations or higher precentages with the following exception
in the category of "percent of year below 10^{-6}", high ranks correspond to lower precentages

Figure Q-2. 1,3-Butadiene % of samples below detection limit

1,3-Butadiene Percent of Samples Below Limit

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				1		2	4	4	4	3
Lynchburg Ferry						3	5	4	4	3
Wallisville						2	5	4	4	3
Tx City 34th St						3	4	4	4	3
Lake Jackson						2	4	4	4	3
Mustang Bayou						3	5	4	4	3
Danciger						2	4	4	4	3
Clinton	4	4	4	4	4	4	4	4	4	3
Deer Park	5	3	3	4	4	4	4	5	4	3
Milby Park								4	4	3
Channel- view				1	4	4	4	4	4	3
Cesar Chavez							3	4	4	3

This statistic is the percent of samples where the concentration was below the detection limit out of the total number of samples available. These samples were replaced with 1/2 the detection limit for statistical calculations.

Figure R-2. 1,3-Butadiene frequency of detection

1,3-Butadiene Frequency of Detect

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				17%		49%	86%	77%	92%	87%
Lynchburg Ferry						51%	79%	83%	88%	89%
Wallisville						51%	87%	74%	72%	86%
Tx City 34th St						53%	90%	87%	86%	87%
Lake Jackson						46%	76%	80%	87%	89%
Mustang Bayou						33%	83%	87%	86%	85%
Danciger						47%	90%	84%	84%	87%
Clinton	86%	73%	81%	67%	55%	43%	80%	80%	89%	86%
Deer Park	74%	61%	63%	74%	70%	50%	68%	69%	81%	86%
Milby Park								73%	86%	89%
Channel- view				21%	75%	57%	52%	65%	81%	80%
Cesar Chavez							57%	88%	84%	88%

This statistic is the number of samples where a concentration was detected out of the total number of samples available.

Figure S-2. 1,3-Butadiene number of samples

1,3-Butadiene Number of Samples

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				1487		4321	7511	6727	8022	7580
Lynchburg Ferry						4448	6967	7311	7689	7798
Wallisville						4492	7617	6454	6342	7563
Tx City 34th St						4660	7944	7623	7502	7587
Lake Jackson						4008	6701	7032	7626	7777
Mustang Bayou						2898	7272	7601	7524	7436
Danciger						4083	7883	7374	7341	7663
Clinton	7494	6408	7086	5865	4844	3749	7043	6976	7753	7543
Deer Park	6509	5349	5543	6514	6162	4367	5939	6047	7137	7536
Milby Park								6413	7573	7797
Channel- view				1879	6571	4953	4551	5675	7081	7021
Cesar Chavez							5024	7712	7378	7665

This statistic is the number of samples where a concentration was detected.

Figure T-2. 1,3-Butadiene coefficient of variation

1,3-Butadiene Coefficient of Variation

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HRM-3				2.18		3.23	3.28	4.74	6.14	2.26
Lynchburg Ferry						2.66	4.29	5.48	3.16	2.76
Wallisville						2.39	2.51	2.94	6.01	5.13
Tx City 34th St						7.96	6.22	10.22	3.71	2.62
Lake Jackson						2.28	1.69	1.96	3.09	2.47
Mustang Bayou						10.05	5.26	6.97	6.31	9.34
Danciger						2.93	1.23	2.14	2.06	3.52
Clinton	4.31	2.89	3.39	2.40	2.61	2.56	2.97	3.28	5.22	2.51
Deer Park	3.62	2.49	2.76	5.79	3.00	6.72	2.99	1.98	1.36	13.63
Milby Park								2.46	17.80	2.12
Channel- view				6.42	3.42	3.08	3.00	4.72	4.28	4.31
Cesar Chavez							3.16	3.60	3.53	2.47

This statistic may indicate non-normality if it exceeds 1.2.

Figure A-3. Benzene and 1, 3-Butadiene Combined Inhalation Risk