Twenty More Answers

Further Data and Technical Background for

"Where Does Houston's Smog Come From?"

The Sources of Houston's Air Pollution and What's Needed to Clear the Air

This report is intended to be a technical reference to supplement "Where Does Houston's Smog Come From" (October 2003). Please note that from time to time updates may be posted to GHASP's website in response to any requests for clarifications. Each of the following sections is referenced to a specific statement or exhibit in the text of the main report.

A. The Clean Air Act specifies that air pollution should not increase an individual's risk of getting cancer by more than one in one million.

As stated in section 112(c)(1) of the Clean Air Act, "in the case of hazardous air pollutants emitted by sources in the category that may result in cancer in humans, a determination that no source in the category (or group of sources in the case of area sources) emits such hazardous air pollutants in quantities which may cause a lifetime risk of cancer greater than one in one million to the individual in the population who is most exposed to emissions of such pollutants from the source (or group of sources in the case of area sources)" (http://www.epa.gov/air/caa/caa112.txt).

B. Ozone, formaldehyde, and acrolein often reach levels at which they cause acute health effects such as respiratory distress and eye irritation almost immediately upon exposure.

The acute health effects of ozone are discussed in section (C).

For other pollutants, GHASP followed methods recommended by the California Environmental Protection Agency study, "The Determination of Acute Reference Exposure Levels for Airborne Toxicants" (March 1999). The discussion that follows is abridged from California EPA's study. GHASP consulted with toxicologists to modify the California EPA approach to accommodate the data sets available for the Houston region.

The reference exposure level (**REL**) is the concentration level at or below which no adverse health effects are anticipated for a specified exposure duration. RELs are based on the most sensitive, relevant, adverse health effect reported in the medical and toxicological literature. RELs are designed to protect the most sensitive individuals in the population by the inclusion of margins of safety. Since margins of safety are incorporated to address data gaps and uncertainties, exceeding the REL does not automatically indicate an adverse health impact.

The California EPA developed a method for deriving acute (one-hour) inhalation Reference Exposure Levels (RELs) for hazardous airborne substances. The acute REL is an exposure that is not likely to cause adverse effects in a human population, including sensitive subgroups, exposed to that concentration for one hour on an intermittent basis.

Although California EPA uses a one-hour modeled maximum concentration to evaluate “acute” exposures, GHASP was unable to obtain such information due to the nature of data collection in the Houston region. Instead, GHASP used the 95th percentile value for each year of available data, and averaged these values when more than one year of data was available.

GHASP followed the California EPA method of using a hazard index approach in order to evaluate “acute” exposures and potential public health impacts from such exposure. The hazard index is the ratio of the measured (95th percentile) concentration to the acute reference exposure level.

In cases where the cumulative hazard index exceeds one, GHASP identified those non-ozone pollutants with a ratio greater than 0.01 as of potential concern. This approach was selected because the maximum one-hour measure is likely to be significantly higher than the 95th percentile value, which is often based on a 24-hour sample rather than a one-hour sample. GHASP effectively used a factor of 100 to adjust the 95th percentile value to a maximum one-hour value. While this may seem high, this factor of 100 is primarily intended as a screening value to identify compounds that contribute significantly towards a cumulative acute exposure of concern.

In keeping with the California EPA approach, these findings do not necessarily mean adverse effects will occur at the indicated exposure levels. Rather, it is an indication of the erosion of the margin of safety for exposure to that chemical. Unfortunately, there is no accepted method for converting ambient pollution measurements into estimates of health impacts for many of the air pollutants routinely measured in the Houston region.

Table B-1 presents the acute RELs used by GHASP in this analysis. GHASP reviewed all pollutants monitored in the Houston region, but identified only 15 with acute RELs or MRLs (Minimum Risk Levels) established by a state or federal agency. Clearly, there are other pollutants present in Houston’s air that may be associated with acute health effects.

Tables B-2, B-4, and B-6 present the 95th percentile ambient pollution data for these 15 chemicals.[1] Tables B-3, B-5, and B-7 present the hazard index, or acute exposure

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[1] The source of formaldehyde data in these tables is the Texas Commission on Environmental Quality. It collects 1-hour and 24-hour samples of oxygenated VOCs. Samples are collected on dinitrophenylhydrazine (DNPH) coated silica cartridges and then analyzed by high performance liquid chromatography (HPLC). At sites where both the 1-hour and 24-hour 95th percentile value was provided by TCEQ, GHASP selected the higher value for each year and averaged across all years. The following years are included in the TCEQ database: Clinton (C403) 1998-2002; Haden Rd. (C603/HRM-3) 2001. All other data in these tables are from the Texas Commission on Environmental Quality, which measures these pollutants using two systems. The community air toxics monitoring network (CATMN) uses 24-hour canister samples and the semi-continuous automated gas chromatograph (auto-GC) system collects 1-hour data. At sites where both the 1-hour and 24-hour 95th percentile value was provided by TCEQ, GHASP selected the higher value for each year and averaged across all years. Most sites include six years of data (1997-2002).

index, for the four chemicals measured at the 95th percentile at 1% or greater of the acute REL.

Other than ozone, acrolein is the pollutant with the highest acute exposure index value. As discussed in the source notes, acrolein is not routinely monitored in the Houston region. In addition to the study referenced in Table B-4, the Harris Galveston Community Air Monitoring Program (HG-CAMP) collected a number of air samples with levels of acrolein in excess of 1 ppb. Because these samples were taken in response to specific concerns (rather than on a regular sampling schedule), and because the detection limit for acrolein using this sample is well above the acute REL, these data are not used in this study. However, the HG-CAMP data do provide qualitative evidence that acrolein is frequently found at levels that could cause acute health symptoms.

GHASP made this extra effort to assess acrolein because the EPA identified acrolein as the only air toxic that poses “the greatest relative hazard for effects other than cancer” on a nationwide basis. Acrolein's reference concentration is based on irritation of the lining of the respiratory system. Despite being identified as an air toxic of nationwide concern, GHASP is unaware of any routine monitoring for acrolein in the Houston region.

Ozone data were not analyzed using this method because the federal health standard for ozone provides a more familiar and roughly equivalent reference level for evaluating the frequency and severity of its health effects, as discussed below.

Table B-1: Acute Reference Exposure Levels[2]

	AREL (ppbv)	Source
1,1,1-Trichloroethane	2000	CalAREL
1,1-Dichloropropane	50	ATSDR
Acrolein	0.083	CalAREL
Benzene	50	CalAREL
Bromomethane	50	CalAREL
Carbon Tetrachloride	200	CalAREL
Chloroform	31	CalAREL
Formaldehyde	77	CalAREL
MTBE	2000	ATSDR
Methylene Chloride	600	CalAREL
Styrene	92	CalAREL
Tetra/per-chloroethylene	5000	CalAREL
Toluene	200	CalAREL
Trichloroethylene	1000	CalAREL
Vinyl Chloride	2000	ATSDR

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[2] Sources: CalAREL (California Environmental Protection Agency), “The Determination of Acute Reference Exposure Levels for Airborne Toxicants” (March 1999). (www.oehha.org/air/chronic_rels/) and ATSDR (Agency for Toxic Substances and Disease Registry), “Minimal Risk Levels (MRLs) for Hazardous Substances” (January 2003). (www.atsdr.cdc.gov/mrls.html)

Table B-2: East Ship Channel Area Acute Exposure Data
95th Percentile Values, parts per billion by volume

	C120	C403	C167	C169	C603 (HRM-3)
	Allendale	Clinton	Galena Park	Milby Park	Haden Rd.
1,1,1-Trichloroethane	0.24	0.15	0.08	0.03	0.18
1,1-Dichloropropane	0.01	0.01	0.01	0.01	0.01
Acrolein					
Benzene	3.55	1.96	4.02	1.49	1.89
Bromomethane	0.04	0.03	0.01	0.01	0.01
Carbon Tetrachloride	0.30	0.16	0.15	0.17	1.39
Chloroform	0.12	0.08	0.12	0.08	0.14
Formaldehyde		19.41			12.49
MTBE	7.62	6.40	11.56	5.96	3.65
Methylene Chloride	0.31	0.32	0.34	0.18	0.35
Styrene	0.45	0.28	0.31	3.29	0.93
Tetra/per-chloroethylene	0.12	0.10	0.07	0.05	0.07
Toluene	3.20	2.97	2.79	2.20	2.90
Trichloroethylene	0.03	0.03	0.03	0.03	0.04
Vinyl Chloride	0.13	0.04	0.07	0.01	0.28

Table B-3: East Ship Channel Area Acute Exposure Index (values > 0.00)

	C120	C403	C167	C169	C603 (HRM-3)
	Allendale	Clinton	Galena Park	Milby Park	Haden Rd.
Benzene	0.07	0.04	0.08	0.03	0.04
Formaldehyde		0.25			0.16
MTBE	0	0	0.01	0	0

Source: Ratio of value in Table B-2 to value in Table B-1.

Table B-4: West Ship Channel, Channelview and Baytown Areas Acute Exposure Data
95th percentile values, parts per billion by volume

	C148	C15	C35	Special	C166	C145
	Baytown	Channelview	Deer Park	La Porte[3]	San Jacinto	Shoreacres
1,1,1-Trichloroethane	0.05	1.55	0.14		0.04	0.05
1,1-Dichloropropane	0.01	0.01	0.01		0.01	0.01
Acrolein				0.28		
Benzene	1.13	2.36	1.87	1.8	4.17	2.59
Bromomethane	0.01	0.01	0.01		0.01	0.01
Carbon Tetrachloride	0.13	0.18	0.18		0.22	0.18
Chloroform	0.04	0.09	0.08		0.13	0.32
Formaldehyde		13.07	15.95			
MTBE	1.99	2.53	2.74		6.26	1.52
Methylene Chloride	0.48	0.31	0.35		0.57	0.34
Styrene	0.09	1.07	0.1		0.25	0.29
Tetra/per-chloroethylene	0.03	0.06	0.08		0.03	0.04
Toluene	1.61	2.5	2.08	3.11	2.25	4.07
Trichloroethylene	0.04	0.07	0.04		0.01	0.1
Vinyl Chloride	0.11	0.28	0.21		0.78	0.01

Table B-5: West Ship Channel, Channelview and Baytown Areas Acute Exposure Index
(values > 0.00)

	C148	C15	C35	Special	C166	C145
	Baytown	Channelview	Deer Park	La Porte	San Jacinto	Shoreacres
Acrolein				3.42		
Benzene	0.02	0.05	0.04	0.04	0.08	0.05
Chloroform	0	0	0	0	0	0.01
Formaldehyde		0.17	0.21			

Source: Ratio of value in Table B-2 to value in Table B-1.

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[3] Dr. Daniel Riemer, University of Miami, Rosenstiel School of Marine and Atmospheric Science, Division of Marine and Atmospheric Chemistry, provided an unpublished data set collected at the La Porte Airport on 8/19/2000 – 9/12/2000 as part of TexAQS 2000. The data represent 5 minute average values collected approximately twice an hour. This data set is used in this analysis because it is the only publicly-available measurement of acrolein for Houston besides individual samples. Because it represents only a month of sampling, its results should be considered with that limitation in mind.

Table B-6: Houston Urban, Brazoria and Galveston Areas Acute Exposure Data
95th percentile values, parts per billion by volume

	C8	C53	C26	C11	C147	C100	C34
	Aldine	Bayland Park	NW Harris	Clute	Texas City	Texas City	Galveston
1,1,1-Trichloroethane	0.15	0.06	0.07				
1,1-Dichloropropane	0.01	0.01	0.01				
Acrolein							
Benzene	1.53	1.2	0.99	1.35	3.01	1.82	0.58
Bromomethane	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Carbon Tetrachloride	0.20	0.13	0.13	0.21	0.12	0.18	0.13
Chloroform	0.06	0.04	0.02	0.06	0.02	0.13	0.03
Formaldehyde		12.87					
MTBE	3.50	2.26	0.83	1.5	1.8	1.24	0.48
Methylene Chloride	0.35	0.25	0.25	5.32	0.16	0.38	0.19
Styrene	0.21	0.09	0.1	0.19	0.13	0.13	0.09
Tetrachloroethylene	0.06	0.12	0.05				
Toluene	2.67	3.75	1.53	1.38	1.92	1.33	1.13
Trichloroethylene	0.03	0.02	0.03	0.22	0.01	0.03	0.01
Vinyl Chloride	0.06	0.02	0.02	0.32	0.04	0.11	0.02

Table B-7: Houston Urban, Brazoria and Galveston Areas Acute Exposure Index
(values > 0.00)

	C8	C53	C26	C11	C147	C100	C34
	Aldine	Bayland Park	NW Harris	Clute	Texas City	Texas City	Galveston
Benzene	0.03	0.02	0.02	0.03	0.06	0.04	0.01
Formaldehyde		0.17					

Source: Ratio of value in Table B-2 to value in Table B-1.

C. Figure 1: Unhealthy Air Days in the Houston Region

The Air Quality Index is one way to track the number of unhealthy air days in the Houston region. For Houston, this index emphasizes the importance of ozone and fine particulate matter as causes of acute health problems.

Information on the Air Quality Index (AQI) is available from three locations.

- For general information, the US Environmental Protection Agency's AIRNow website has educational information about the Air Quality Index (http://www.epa.gov/airnow/index.html).
- To download the data presented below, the US EPA makes AQI data available at http://www.epa.gov/air/data/reports.html.
- The details of how the US EPA uses the AQI are explained in *Guidelines For Reporting Of Daily Air Quality - Air Quality Index (AQI)* (July 1999).

GHASP downloaded data from 2000-2002 for the Houston, Galveston-Texas City and Brazoria Metropolitan Statistical Areas. These three datasets were merged by selecting the highest AQI value among the three regions to find the AQI value for the Houston region.

Table C-1: Air Quality Index Category by Month, 2000-2002 Houston-Galveston-Brazoria
Average Number of Days

Year	Good	Moderate	Unhealthy for Sensitive Groups	Unhealthy	Very Unhealthy
January	19.3	11.3	0.3		
February	15.3	13.0			
March	16.0	13.3	1.7		
April	10.7	14.7	4.3	0.3	
May	10.7	17.7	1.7	0.7	0.3
June	13.3	9.0	5.3	2.0	0.3
July	7.7	16.7	4.0	2.3	0.3
August	10.7	10.0	7.0	2.7	0.7
September	13.0	7.3	6.0	3.0	0.7
October	18.3	9.3	2.7	0.7	
November	19.3	9.3	0.7	0.7	
December	20.0	11.0			

Source: GHASP analysis of US Environmental Protection Agency data (see above).

Environmental agencies began routine monitoring for fine particulates ($PM_{2.5}$) in late 1999. These new data had a dramatic impact on the AQI data for Houston: between 1998 and 2000, the number of “good” days drops suddenly. Because this change is due to improved information about our air quality, GHASP did not use data prior to 2000 for this analysis. While ozone forms more readily in warm weather, levels of fine particulates routinely reach the moderate level in every month of the year. It is worth noting that many health experts consider the AQI to be somewhat less protective for fine particulates than it should be, and encourage public health agencies to issue warnings when fine particulate levels are in the upper end of the moderate range (for example, AQI values of 75 – 100 would be the upper end of the moderate range).

Table C-2: Annual AQI Data, Houston-Galveston-Brazoria (number of days)

Year	Good	Moderate	Unhealthy for Sensitive Groups	Unhealthy	Very Unhealthy
2000	161	150	37	14	4
2001	170	146	33	14	2
2002	192	132	31	9	1

Source: GHASP analysis of US Environmental Protection Agency data (see above).

The Texas Commission on Environmental Quality provides summaries of air pollution events on its website. These summaries[4] often include maps, charts, and other information describing the source of the air pollution event and factors that affected its distribution. In table C-3, a “contributing cause” is listed for each event; particulate episodes in Houston are often associated with some external contribution that combines

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[4] www.tnrcc.state.tx.us/updated/air/monops/airpollevents/2003/sigevents_2003.html

with local particulates to create high levels of particulates. The “contributing cause” may be more or less than half the total amount of particulates.

An effort to drastically reduce particulate episodes in the Houston region could include three components. First, reductions in local sources of particulates (primarily diesel and industrial) could reasonably achieve a 10% reduction in particulate levels. Considering the AQI values presented in Table C-3, 7 of the 12 days listed had AQI values of 111 or less. Second, reductions in fireworks use could eliminate the worst day on the list and also one other day. Finally, full implementation of the Clean Air Act resulting in cleanup of Midwestern power plants could reduce or eliminate most of the remaining days on the list. Of the 12 days with high AQI values (over 3 years of data), only one day of unhealthy particulate levels might not be resolved through these three steps.

Table C-3: Unhealthy Air Days with High Levels of Particulates (2000 – June 2003)

Date	AQI Category	AQI Value	Pollutant	AQI Value for Ozone	Contributing Cause
1/1/00	Unhealthy for Sensitive Groups	102	PM_{10}	Lower	Fireworks
9/6/00	Unhealthy for Sensitive Groups	107	$PM_{2.5}$	Higher	Fires in E. Texas
4/4/01	Unhealthy for Sensitive Groups	127	$PM_{2.5}$	Lower	Fires in Mexico
9/16/01	Unhealthy for Sensitive Groups	107	$PM_{2.5}$	Higher	Midwest pollution
11/11/01	Unhealthy for Sensitive Groups	111	$PM_{2.5}$	Higher	Fires in E. Texas
11/12/01	Unhealthy for Sensitive Groups	108	$PM_{2.5}$	Lower	Fires in E. Texas
9/12/02	Unhealthy for Sensitive Groups	133	$PM_{2.5}$	Higher	Midwest pollution
9/13/02	Unhealthy for Sensitive Groups	134	$PM_{2.5}$	Higher	Midwest pollution
9/14/02	Unhealthy for Sensitive Groups	127	$PM_{2.5}$	Higher	Midwest pollution
9/15/02	Unhealthy for Sensitive Groups	106	$PM_{2.5}$	Lower	Midwest pollution
1/1/03	Unhealthy	152	$PM_{2.5}$	Lower	Fireworks
5/11/03	Unhealthy for Sensitive Groups	107	$PM_{2.5}$	Lower	Fires in Mexico

Source: GHASP analysis of US Environmental Protection Agency data (see above), information from “Air Pollution Events” pages on the website of the Texas Commission on Environmental Quality and private correspondence with Bryan Lambeth, Texas Commission on Environmental Quality.

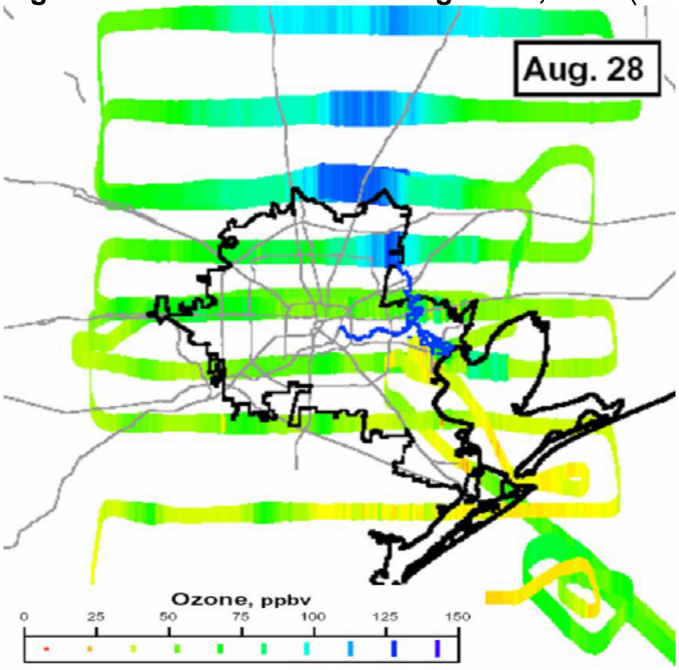
D. Ozone forms most frequently near industrial areas . . . [and plumes] have been observed passing through Beaumont/Port Arthur, Victoria, and Conroe.

“Almost without exception, air parcels with very high ozone concentrations, observed by aircraft during the Texas Air Quality Study, had back trajectories that indicated a substantial contribution of emissions from industrial source regions. These air parcels also had chemical compositions that were representative of industrial sources, rather than typical urban sources.”

> - Texas Commission on Environmental Quality, Technical Analysis Division, *Accelerated Science Evaluation of Ozone Formation in the Houston/Galveston Area*, Summary (November 13, 2002), prepared by Science Synthesis Committee.

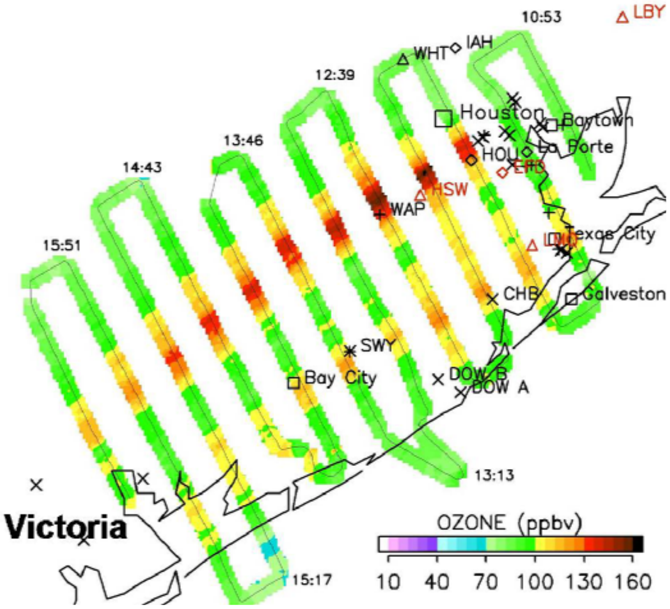
During the Texas Air Quality Study, plumes of ozone with their origin in the industrial areas of Houston were observed near Beaumont/Port Arthur (September 1, 2000), Victoria (September 6, 2000), and Conroe (August 26-28, 2000). Although aircraft found ozone levels in the plumes exceeded the federal health standard, the lack of ground monitoring stations underneath the plumes meant that the extent of the air pollution would not have been noted if the aircraft had not been participating in the study. For example, there are no ozone monitor data available to the public in real time from the Victoria area. On August 27 and 28, the relatively extensive Houston-area monitoring network missed the ozone plume located by aircraft. It passed just to the east of the only Montgomery County monitor.

Figure D-1: Ozone Plume of August 28, 2000 (NOAA aircraft data)



Source: National Oceanic and Atmospheric Administration.

Figure D-2: Ozone Plume of September 6, 2000 (NOAA aircraft data)



Source: National Oceanic and Atmospheric Administration.

E. Formaldehyde is a key factor in Houston's unusually rapid ozone formation.

A number of Texas Air Quality Study scientists examined the role of formaldehyde in Houston's unusually rapid ozone formation. According to one report, "petrochemical emissions are indeed the dominant source of extreme [formaldehyde] concentrations in Houston." The report examines in detail the role of formaldehyde in the formation of ozone.

B. P. Wert et al, "Signatures of Terminal Alkene Oxidation in Airborne Formaldehyde Measurements During TexAQS 2000." As reported in NOAA Aeronomy Laboratory, "Texas 2000 Air Quality Study – Phase II: Analysis of NOAA Data" (March 2003). Available at:
www.tnrcc.state.tx.us/air/aqp/airquality_contracts.html#da11.

F. Laboratory and occupational studies on the health effects of formaldehyde and acrolein have not been followed up with population studies like those on ozone.

GHASP reviewed the health science supporting the claims that the air pollution discussed in this report is related to health effects. Because of ethical concerns and funding limitations, there is often considerable uncertainty about the health effects of many pollutants.

- The Scorecard.org website (Environmental Defense) provides extensive information and links to agency website data related to the health effects of many pollutants. Specific chemicals can be found from http://www.scorecard.org/chemical-profiles/index.tcl.

- The most useful synthesis of health effects evidence is the US Environmental Protection Agency's Integrated Risk Information System (IRIS is at www.epa.gov/iris/). Formaldehyde and acrolein are both included in this system.

Formaldehyde has been studied primarily through the use of epidemiologic studies, such as occupational and residential exposure studies. These studies are considered to be of limited value because of the possible exposures to other agents. More specific studies have been done using laboratory animals.

No chronic studies of humans exposed to acrolein are available. Health effects data for acrolein rely primarily on studies done using laboratory animals and some studies and case histories involving acute exposures by humans to acrolein.

G. Figure 2: Air Pollution and Increased Cancer Risk in Harris County.

Ideally, exposure and health data would make it possible to determine the actual number and types of diseases caused by air pollution in the Houston region. Such data would help the public and government press for appropriate pollution controls to eliminate disease caused by air pollution. However, such data are not available now nor are they likely to be available in the near future.

To overcome these limitations GHASP used the best available data: long-term monitoring data collected by the Texas Commission on Environmental Quality, as well as data from other state agencies and a few university research projects. GHASP then combined these data with risk assessment values compiled by Environmental Defense on its Scorecard.org website. The discussion that follows is abridged from http://www.scorecard.org/chemical-profiles/def/rav_edf.html.

Risk assessment values (**RAVs**) are numbers that help define the level of health risk posed by a toxic chemical. RAVs are derived from dose-response data obtained from human or animal studies to provide a summary measure of the toxicity of a chemical. Regulatory agencies calculate separate numbers for carcinogens (potencies) and non-carcinogens (reference doses or concentrations). Cancer potencies express how much added cancer risk is associated with lifetime exposure to a unit dose of a chemical (presented as the additional cancer risk associated with an average daily dose of one milligram of a chemical per kilogram of bodyweight). Reference doses and concentrations are estimates of the daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects over a lifetime.

Risk assessment values or media quality standards can be used to evaluate the health risks posed by exposures to toxic chemicals. Media quality standards can be compared directly to information about the concentration of a chemical in the environment to identify potential health hazards. If a chemical concentration exceeds a relevant media quality standard, action to reduce environmental contamination or exposure is warranted. Unfortunately, there are relatively few chemicals with standards that define allowable concentrations in air, water, or food. More chemicals have risk assessment values, which can be combined with information about the dose of a chemical that someone receives to characterize health risks.

Scorecard includes all risk assessment values that have been developed by the state of California or by national regulatory agencies, such as the U.S. Environmental Protection Agency or the Agency for Toxic Substances and Disease Registry. A prioritization scheme determines which agency's RAV will be used if multiple agencies have developed RAVs for the same chemical. To ensure that RAVs are derived as consistently as possible, Scorecard adopts the agency with largest number of RAVs available as its priority source. California regulatory agencies have derived more cancer potency values and inhalation reference concentrations for chemical than any federal agency, so Scorecard preferentially adopts these RAVs. Other sources are then used if needed, ordered by the extent to which RAVs have undergone either scientific or regulatory review.

Scorecard risk assessment values are available from the website, along with a reference citation for each RAV. For cancer, GHASP used the inhalation cancer potencies available from Scorecard. The inhalation cancer potencies for the air pollutants of significance (as identified by monitoring or other methods) are listed in Table G-1.

Table G-1: Cancer Risk Assessment Values
Added cancers per million, per ppbv long-term pollution exposure

Pollutant	Inhalation Cancer Potency	Source
1,1,2,2-Tetrachloroethane	0.00000845	OEHHA-TCD
1,1,2-Trichloroethane	0.00000293	OEHHA-TCD
1,1-Dichloroethane	0.00000040	OEHHA-TCD
1,1-Dichloroethylene	0.00008647	HEAST
1,2-Dibromoethane	0.00000924	OEHHA-TCD
1,2-Dichlorethane	0.00000519	OEHHA-TCD
1,2-Dichloropropane	0.00000216	OEHHA-TCD
1,3-Butadiene	0.00007684	OEHHA-TCD
Acetaldehyde	0.00000150	OEHHA-TCD
Acrylonitrile	0.00013363	OEHHA-TCD
Arsenic	0.00107695	OEHHA-TCD
Benzene	0.00000908	OEHHA-TCD
Carbon Tetrachloride	0.00000668	OEHHA-TCD
Chloroform	0.00000109	OEHHA-TCD
Chromium	0.00564231	SCDM
cis-1,3-Dichloro-1-Propene	0.00000815	HWIR
Crotonaldehyde	0.00018937	HEAST
Formaldehyde	0.00000489	OEHHA-TCD
Methyl tert-butyl ether (MTBE)	0.00000007	OEHHA-TCD
Methylene Chloride	0.00000029	OEHHA-TCD
Nickel	0.00010831	OEHHA-TCD
Tetrachloroethylene	0.00000087	OEHHA-TCD
trans-1,3-dichloropropylene	0.00000815	HWIR
Trichloroethylene	0.00000037	OEHHA-TCD
Vinyl Chloride	0.00001967	OEHHA-TCD

Sources: OEHHA-TCD (California EPA, Office of Environmental Health Hazard Assessment, *Toxicity Criteria Database - OEHHA Cancer Potency Values*, www.oehha.ca.gov/risk/ChemicalDB/, December 2002.), HEAST (US EPA, Office of Research and Development. Health Effects Assessment Summary Tables. July 1997.), HWIR (US EPA, Office of Solid Waste. *Hazardous Waste Identification Rule Technical Support Documents: Risk Assessment for Human and Ecological Receptors,* Initial (8/95) and Supplemental (11/95) Technical Support Documents.) and SCDM (US EPA, Office of Emergency Response and Remediation, *Superfund Chemical Data Matrix,* www.epa.gov/superfund/resources/prescore/prescdm.htm.); as compiled by Environmental Defense at www.scorecard.org/chemical-profiles/def/rav_edf.html.

The added cancer risk for diesel particulates was calculated using a slightly different process from other air toxics because the ambient data come from a different source. The inhalation cancer potency for diesel particulates is 0.0003 per ug/m^3 (OEHHA-TCD). There is no routine monitoring for diesel particulates, but research by Dr. Matthew Fraser (Rice University) provides some information on diesel particulate levels at four sites in the Houston region, as presented in Table G-2.

Table G-2: Added Diesel Cancer Risk Estimate

Site	Measured Diesel $PM_{2.5}$ (ug/m^3)	Percent of $PM_{2.5}$Sample	Long-term[1] Total $PM_{2.5}$ (ug/m^3)	Calculated Diesel $PM_{2.5}$ (ug/m^3)	Added Cancer Risk (per million)
Galveston	0.5[2]	4%	10.1	0.4	120
LaPorte	1.1[3]	9%	12.3	1.1	330
Haden Rd. (HRM-3)	2.0[3]	12%	15.0	1.8	540
Clinton Dr.	3.7[2]	17%	13.4	2.3	690
Aldine	1.6[3]	11%	12.6	1.3	390

[1] Long-term average $PM_{2.5}$ calculated using 2000-2002 data, except at Haden Road where 2002 data were not available, so 1999-2001 data were used.
[2] Diesel $PM_{2.5}$ measurements made during 1997-1998.
[3] Diesel $PM_{2.5}$ measurements made during August-September 2000.
Source: Fraser, M.P., Z. W. Yue and B. Buzco, "Organic Speciation and Source Apportionment of Fine PM during TexAQS 2000" (November 2002 Presentation).

The added cancer risk for air toxics (other than diesel particulates and unmonitored pollutants) is calculated by multiplying the inhalation cancer potency (Table G-1) bythe observed long-term mean concentration in parts per billion (Tables G-3 through G-7), times one million. For example, if an individual's estimated cancer risk due to genetics and lifestyle choices were 100 in a million, and that individual inhaled an average concentration of 0.3046 ppb of butadiene over her lifetime, then her total estimated risk of getting cancer would be about 123 in a million (see Table G-7).

The long-term mean concentration of the pollutants listed below are available from the Texas Commission on Environmental Quality. The TCEQ measures these pollutants using two systems. The community air toxics monitoring network (CATMN) uses 24-hour canister samples and the semi-continuous automated gas chromatograph (auto-GC) system collects 1-hour data. At sites where both the 1-hour and 24-hour mean percentile value was provided by TCEQ, GHASP selected the higher value for each year and averaged across all years. Most sites include six years of data (1997-2002).

Table G-3: East Ship Channel Area Long Term Air Toxic Concentrations and Added Cancer Risk

	Allendale (C120)		Clinton (C403)		Galena Park (C167)		Milby Park (C169)		Haden Rd.[1] (C603)	
	ppb	cancer	ppb	cancer	ppb	cancer	ppb	cancer	ppb	cancer
1,1,2,2-Tetrachloroethane			0.0061	0.0500	0.0050	0.0400	0.0050	0.0400	0.0052	0.0400
1,1,2-Trichloroethane	0.0062	0.0200	0.0055	0.0200	0.0054	0.0200	0.0050	0.0100	0.0051	0.0100
1,1-Dichloroethane	0.0064	0.0000	0.0057	0.0000	0.0050	0.0000	0.0052	0.0000	0.0055	0.0000
1,1-Dichloroethylene	0.0075	0.6500	0.0070	0.6100	0.0078	0.6700	0.0103	0.8900	0.0086	0.7400
1,2-Dibromoethane			0.0057	0.0500	0.0050	0.0500	0.0050	0.0500	0.0050	0.0500
1,2-Dichlorethane	0.0116	0.0600	0.0101	0.0500	0.0077	0.0400	0.0059	0.0300	0.0175	0.0900
1,2-Dichloropropane	0.0070	0.0200	0.0050	0.0100	0.0052	0.0100	0.0050	0.0100	0.0053	0.0100
1,3-Butadiene	1.4226	109.3200	0.5520	42.4200	0.4756	36.5500	3.1908	245.1900	0.4197	32.2500
Acetaldehyde			1.6104	2.4100					1.5525	2.3300
Benzene	0.9833	8.9300	0.9056	8.2200	1.5030	13.6500	0.7176	6.5100	0.9126	8.2900
Carbon Tetrachloride	0.1253	0.8400	0.0808	0.5400	0.0707	0.4700	0.0760	0.5100	0.3488	2.3300
Chloroform	0.0461	0.0500	0.0203	0.0200	0.0297	0.0300	0.0241	0.0300	0.0410	0.0400
cis-1,3-Dichloro-1-Propene			0.0050	0.0400	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400
Crotonaldehyde			0.0648	12.2800					0.0265	5.0200
Formaldehyde			3.9679	19.3800					3.5091	17.1400
Methyl tert-butyl ether (MTBE)	2.3192	0.1700	2.3494	0.1700	3.4066	0.2500	3.0421	0.2200	1.0898	0.0800
Methylene Chloride	0.1429	0.0400	0.1631	0.0500	0.0771	0.0200	0.0432	0.0100	0.1010	0.0300
Tetrachloroethylene	0.0334	0.0300	0.0199	0.0200	0.0150	0.0100	0.0093	0.0100	0.0154	0.0100
trans-1,3-dichloropropylene			0.0050	0.0400	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400
Trichloroethylene	0.0098	0.0000	0.0093	0.0000	0.0112	0.0000	0.0115	0.0000	0.0148	0.0100
Vinyl Chloride	0.0245	0.4800	0.0096	0.1900	0.0120	0.2400	0.0103	0.2000	0.0524	1.0300

Source: See discussion in text.

Table G-4: West Ship Channel Area, Channnelview and Baytown Areas Long Term Air Toxic Concentrations and Added Cancer Risk

	Baytown (C148)		Channelview (C15)		Deer Park (C35)		San Jacinto (C166)		Shoreacres (C145)	
	ppb	cancer	ppb	cancer	ppb	cancer	ppb	cancer	ppb	cancer
1,1,2,2-Tetrachloroethane	0.0050	0.0400	0.0055	0.0500	0.0051	0.0400	0.0050	0.0400	0.0050	0.0400
1,1,2-Trichloroethane	0.0052	0.0200	0.0051	0.0100	0.0050	0.0100	0.0072	0.0200	0.0050	0.0100
1,1-Dichloroethane	0.0050	0.0000	0.0051	0.0000	0.0050	0.0000	0.0050	0.0000	0.0052	0.0000
1,1-Dichloroethylene	0.0103	0.8900	0.0058	0.5000	0.0083	0.7200	0.0056	0.4800	0.0064	0.5500
1,2-Dibromoethane	0.0050	0.0500	0.0054	0.0500	0.0050	0.0500	0.0050	0.0500	0.0050	0.0500
1,2-Dichlorethane	0.0237	0.1200	0.0326	0.1700	0.0505	0.2600	0.2454	1.2700	0.1067	0.5500
1,2-Dichloropropane	0.0052	0.0100	0.0055	0.0100	0.0068	0.0100	0.0072	0.0200	0.0050	0.0100
1,3-Butadiene	0.2498	19.2000	0.4908	37.7200	0.1985	15.2500	0.4214	32.3800	0.1285	9.8700
Acetaldehyde			1.1045	1.6600	1.2151	1.8200				
Benzene	0.5889	5.3500	0.9418	8.5500	0.7159	6.5000	1.3544	12.3000	1.0734	9.7500
Carbon Tetrachloride	0.0594	0.4000	0.1029	0.6900	0.0762	0.5100	0.0722	0.4800	0.0657	0.4400
Chloroform	0.0111	0.0100	0.0301	0.0300	0.0185	0.0200	0.0294	0.0300	0.0562	0.0600
cis-1,3-Dichloro-1-Propene	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400
Crotonaldehyde			0.0208	3.9400	0.0574	10.8700				
Formaldehyde			3.8064	18.5900	4.2308	20.6700				
Methyl tert-butyl ether (MTBE)	0.5771	0.0400	0.8243	0.0600	0.8218	0.0600	1.9018	0.1400	0.5166	0.0400
Methylene Chloride	0.1069	0.0300	0.1067	0.0300	0.1145	0.0300	0.0880	0.0300	0.1210	0.0300
Tetrachloroethylene	0.0109	0.0100	0.0159	0.0100	0.0199	0.0200	0.0124	0.0100	0.0112	0.0100
trans-1,3-dichloropropylene	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400
Trichloroethylene	0.0107	0.0000	0.0191	0.0100	0.0134	0.0000	0.0075	0.0000	0.0406	0.0200
Vinyl Chloride	0.0173	0.3400	0.0541	1.0600	0.0389	0.7700	0.0929	1.8300	0.0094	0.1800

Source: See discussion in text.

Table G-5: Houston Urban Area Long Term Air Toxic Concentrations and Added Cancer Risk

	Aldine (C8)		Bayland Park (C53)		NW Harris (C26)	
	ppb	cancer	ppb	cancer	ppb	cancer
1,1,2,2-Tetrachloroethane	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400
1,1,2-Trichloroethane	0.0068	0.0200	0.0050	0.0100	0.0063	0.0200
1,1-Dichloroethane	0.0064	0.0000	0.0051	0.0000	0.0056	0.0000
1,1-Dichloroethylene	0.0086	0.7400	0.0084	0.7300	0.0185	1.6000
1,2-Dibromoethane	0.0050	0.0500	0.0050	0.0500	0.0050	0.0500
1,2-Dichlorethane	0.0107	0.0600	0.0053	0.0300	0.0060	0.0300
1,2-Dichloropropane	0.0067	0.0100	0.0050	0.0100	0.0050	0.0100
1,3-Butadiene	0.1759	13.5200	0.0939	7.2200	0.0447	3.4300
Acetaldehyde			1.1177	1.6800		
Benzene	0.6684	6.0700	0.4842	4.4000	0.4358	3.9600
Carbon Tetrachloride	0.0770	0.5100	0.0599	0.4000	0.0594	0.4000
Chloroform	0.0188	0.0200	0.0102	0.0100	0.0068	0.0100
cis-1,3-Dichloro-1-Propene	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400
Crotonaldehyde			0.0412	7.8000		
Formaldehyde			3.4018	16.6200		
Methyl tert-butyl ether (MTBE)	1.1045	0.0800	0.7152	0.0500	0.2779	0.0200
Methylene Chloride	0.0897	0.0300	0.0691	0.0200	0.0418	0.0100
Tetrachloroethylene	0.0139	0.0100	0.0241	0.0200	0.0103	0.0100
trans-1,3-dichloropropylene	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400
Trichloroethylene	0.0126	0.0000	0.0073	0.0000	0.0173	0.0100
Vinyl Chloride	0.0127	0.2500	0.0080	0.1600	0.0103	0.2000

Source: See discussion in text.

Table G-6: Brazoria and Galveston Counties Long Term Air Toxic Concentrations and Added Cancer Risk

	Clute (C11)		Texas City (C147)		Texas City (C100)		Galveston (C34)	
	ppb	cancer	ppb	cancer	ppb	cancer	ppb	cancer
1,1,2,2-Tetrachloroethane								
1,1,2-Trichloroethane								
1,1-Dichloroethane								
1,1-Dichloroethylene								
1,2-Dibromoethane								
1,2-Dichlorethane								
1,2-Dichloropropane								
1,3-Butadiene								
Acetaldehyde								
Benzene	0.5093	4.6200	1.1892	10.8000	0.8298	7.5300	0.2658	2.4100
Carbon Tetrachloride	0.1024	0.6800	0.0619	0.4100	0.1027	0.6900	0.0674	0.4500
Chloroform	0.0195	0.0200	0.0077	0.0100	0.0379	0.0400	0.0095	0.0100
cis-1,3-Dichloro-1-Propene	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400
Crotonaldehyde								
Formaldehyde								
Methyl tert-butyl ether (MTBE)	0.3908	0.0300	0.5847	0.0400	0.4374	0.0300	0.1369	0.0100
Methylene Chloride	0.8907	0.2600	0.0884	0.0300	0.1750	0.0500	0.0663	0.0200
Tetrachloroethylene								
trans-1,3-dichloropropylene	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400
Trichloroethylene	0.0519	0.0200	0.0071	0.0000	0.0098	0.0000	0.0176	0.0100
Vinyl Chloride	0.0644	1.2700	0.0087	0.1700	0.0228	0.4500	0.0075	0.1500

Source: See discussion in text.

Data on concentrations of toxic metals in air samples are gathered on particulate filters (much like diesel particulates). These samples are gathered using two size ranges, particles of 10 micrograms/m^3 (PM_{10}) and smaller, and particles of 2.5 micrograms/m^3 ($PM_{2.5}$) and smaller. Since the toxicological information used for the risk values does not specify how small the particles must be to contribute toxicity, the PM_{10} values are the more inclusive measurement of metals exposure (rather than the $PM_{2.5}$ values).

GHASP selected arsenic, chromium, and nickel for analysis based on indications from the analysis in Scorecard. Since Houston is well under the national standard for lead concentrations in ambient air, it was not included. It might be useful to consider other metals in a future analysis for evaluation of trends and total body burden.

It is not clear how or whether $PM_{2.5}$ values are correlated with PM_{10} values. For instance, the smallest ($PM_{2.5}$) particles might be associated with certain sources, and larger particles might be associated with other sources. Thus, while the (PM_{10}) values are presented in Table G-8, it cannot be certain what they might suggest. A first impression suggests that metals exposure may be localized and that regional background levels may be relatively similar regardless of general proximity to industrial area.

Table G-7: Houston Area Long Term Air Toxic Concentrations and Added Cancer Risk, Metals Using PM10 Monitors

PM_{10} Monitor Values	Clinton (C403)		Deer Park (C35)	
	ppb	cancer	ppb	cancer
Arsenic	0.0109	11.70	0.0105	11.27
Chromium	0.0016	9.18	0.0007	3.96
Nickel	0.0016	0.17	0.0016	0.17

Source: See discussion in text.

Table G-8: Houston Area Long Term Air Toxic Concentrations and Added Cancer Risk, Metals Using PM2.5 Monitors

$PM_{2.5}$ Monitor Values	Haden Rd.[1] (C603)		Channelview (C15)		Aldine (C8)		Bayland Park (C53)	
	ppb	cancer	ppb	cancer	ppb	cancer	ppb	cancer
Arsenic	0.0003	0.36	0.0004	0.38	0.0009	0.98	0.0007	0.75
Chromium	0.0005	2.80	0.0005	2.89	0.0005	2.86	0.0003	1.96
Nickel	0.0015	0.16	0.0009	0.10	0.0006	0.06	0.0004	0.04

Source: See discussion in text.

In addition to the TCEQ data in tables G-2 through G-8, air toxics data were also obtained from Dr. Daniel Riemer (University of Miami, Rosenstiel School of Marine and Atmospheric Science, Division of Marine and Atmospheric Chemistry). These unpublished data were collected at the La Porte Airport from 8/19/2000 to 9/12/2000 as part of the Texas Air Quality Study 2000. The data represent 5 minute average values collected approximately twice an hour. This data set is used in this analysis because it is the only publicly- available measurement of acrolein for Houston (see tables B-4 and B-5). It is also included in this section for completeness. Because it represents only a month of sampling, its results should be considered with that limitation in mind. However, it is interesting to note that even over the short sampling period, the La Porte data (table G-7) happen to be similar to long-term average at nearby sites (see table G-4, San Jacinto, Deer Park and Shoreacres monitors).

Table G-9: La Porte Long Term Air Toxic Concentrations and Added Cancer Risk

	La Porte	
	ppb	cancer
1,3-Butadiene	0.3046	23.4100
Benzene	0.7392	6.7100

Source: See discussion in text.

Polycyclic aromatic hydrocarbons (PAHs) were derived from one limited study, although one other study was available (see section K). For data collected in Seabrook, the total mean PAH in air samples (particulate and vapor) is 0.052 micrograms/m^3.

The inhalation cancer potency factor used for PAHs is 0.000336 per micrograms/m^3 of polycyclic organic matter (a broader classification of compounds that includes PAHs) using a value assigned by Environmental Defense on Scorecard “based on EPA risk assessment reports, although the central EPA toxicity databases do not record these values.” (www.scorecard.org/chemical-profiles/ref/rav_edf.html) Based on these two data points, the total added cancer risk due to PAH exposure in the Houston region is estimated as 17.4 per million.

No single monitor in the Houston region measures every pollutant of concern for cancer risk. In order to estimate the total exposure that might be experienced across the diverse range of exposures in the Houston region, GHASP subjectively assigned an exposure value (and hence an added cancer risk value) for each of four conditions.

- **Urban**: Bayland Park and Northwest Harris County are the only “true” urban sites. Aldine is often primarily influenced by urban pollution, but sometimes is directly downwind of relatively nearby industrial sources. Galveston is also an “urban” area but is coastal and thus gets relatively fresh air that is not widely experienced in the Houston urban region. Galveston is also not far from a major industrial complex. All four values were considered. If the Aldine value for a given pollutant was a significant outlier (high) then it was disregarded. If there was a low outlier, then it was assigned to the “low” value. Otherwise, a value that represented the median was used for both “low” and “typical.”

- **Industrial**: Generally the highest or second highest value in the entire data set was used for the “high” category. Among the industrial area sites, the “typical” value was selected from among a cluster of values that generally appeared at the low end of the range. If a cluster was not apparent, a relatively low value was selected for the “typical” value.

The results of this summary appears in Table G-10.

Table G-10: Summary of Houston Region Long Term Air Toxic Concentrations and Added Cancer Risk

	Low Urban		Typical Urban		Typical Industrial		High Industrial	
	ppb	cancer	ppb	cancer	ppb	cancer	ppb	cancer
Diesel Particulates		**120.0000**		**390.0000**		**390.0000**		**690.0000**
1,3-Butadiene	0.0447	**3.4300**	0.0939	**7.2200**	0.4214	**32.3800**	3.1908	**245.1900**
Acetaldehyde	1.1177	1.6800	1.1177	1.6800	1.5525	2.3300	1.6104	2.4100
Crotonaldehyde	0.0412	7.8000	0.0412	7.8000	0.0265	5.0200	0.0648	12.2800
Formaldehyde	3.4018	16.6200	3.4018	16.6200	3.5091	17.1400	4.2308	20.6700
Aldehydes		**26.1000**		**26.1000**		**24.4900**		**35.3600**
PAH		**17.4000**		**17.4000**		**17.4000**		**17.4000**
Arsenic	0.0105	11.2700	0.0105	11.2700	0.0105	11.2700	0.0105	11.2700
Chromium	0.0007	3.96	0.0007	3.96	0.0007	3.96	0.0016	9.18
Nickel	0.0016	0.17	0.0016	0.17	0.0016	0.17	0.0016	0.17
Metals		**15.4000**		**15.4000**		**15.4000**		**20.6200**
Benzene	0.2658	**2.4100**	0.4842	**4.4000**	0.7176	**6.5100**	1.5030	**13.6500**
1,1,2,2-Tetrachloroethane	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400	0.0061	0.0500
1,1,2-Trichloroethane	0.0050	0.0100	0.0063	0.0200	0.0050	0.0100	0.0072	0.0200
1,1-Dichloroethane	0.0051	0.0000	0.0056	0.0000	0.0050	0.0000	0.0057	0.0000
1,1-Dichloroethylene	0.0084	0.7300	0.0084	0.7300	0.0058	0.5000	0.0103	0.8900
1,2-Dibromoethane	0.0050	0.0500	0.0050	0.0500	0.0050	0.0500	0.0175	0.0900
1,2-Dichlorethane	0.0053	0.0300	0.0053	0.0300	0.0101	0.0500	0.2454	1.2700
1,2-Dichloropropane	0.0050	0.0100	0.0050	0.0100	0.0050	0.0100	0.0070	0.0200
Carbon Tetrachloride	0.0594	0.4000	0.0599	0.4000	0.0707	0.4700	0.3488	2.3300
Chloroform	0.0068	0.0100	0.0102	0.0100	0.0203	0.0200	0.0562	0.0600
cis-1,3-Dichloro-1-Propene	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400
Methyl tert-butyl ether (MTBE)	0.2779	0.0200	0.7152	0.0500	0.5166	0.0400	3.4066	0.2500
Methylene Chloride	0.0418	0.0100	0.0691	0.0200	0.1010	0.0300	0.8907	0.2600
Tetrachloroethylene	0.0103	0.0100	0.0139	0.0100	0.0150	0.0100	0.0334	0.0300
trans-1,3-dichloropropylene	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400	0.0050	0.0400
Trichloroethylene	0.0073	0.0000	0.0126	0.0000	0.0093	0.0000	0.0519	0.0200
Vinyl Chloride	0.0080	0.1600	0.0103	0.2000	0.0103	0.2000	0.0929	1.8300
Other Organics		**1.56**		**1.65**		**1.51**		**7.2**
TOTAL		**186**		**462**		**488**		**1,029**

Source: See tables G-2 through G-9, GHASP subjective assessment of data to account for limited data coverage at several monitors.

H. Data about pollution levels in suburban areas is scarcer.

Although there are a number of ozone monitors outside industrial areas, air toxics and particulate matter data are not collected at many of these monitors.

- Particulate data is collected at four non-industrial sites: Conroe, Aldine, Bayland Park, and Galveston. Strong industrial pollution plumes are often observed at Aldine, however. More detailed data on particle composition (important for determining air toxics exposures) is collected only at Aldine and Bayland Park.

- Air toxics data is collected at three non-industrial sites: Aldine, Bayland Park, and Northwest Harris County. Carbonyl samples (formaldehyde, acetaldehyde, crotonaldehyde and other pollutants) are only collected at Bayland Park.

Because of the absence of long-term monitoring data for the entire Houston region, or even studies to determine what variability might be anticipated across the region, it is difficult to speculate on whether pollution levels are lower in Fort Bend County (for example). The reasons that mean formaldehyde concentrations are relatively uniform, for example, may be difficult to determine with data from only five monitoring sites. In contrast, a larger dataset helps suggest that some industrial sources are responsible for the butadiene “hot spots.”

I. For some pollutants, environmental scientists identify a benchmark level of exposure that does not seem to cause chronic diseases or disorders

Ideally, exposure and health data would make it possible to determine the actual number and types of diseases caused by air pollution in the Houston region. Such data would help the public and government press for appropriate pollution controls to eliminate disease caused by air pollution. However, such data are not available now nor are they likely to be available in the near future.

Instead, GHASP used the best available data: long-term monitoring data collected by the Texas Commission on Environmental Quality, other state agencies and a few university research projects. GHASP then combined these data with risk assessment values compiled by Environmental Defense on its Scorecard.org website. The discussion that follows is abridged from http://www.scorecard.org/chemical-profiles/def/rav_edf.html.

Risk assessment values (RAVs) are numbers that help define the level of health risk posed by a toxic chemical. RAVs are derived from dose-response data obtained from human or animal studies to provide a summary measure of the toxicity of a chemical. Regulatory agencies calculate separate numbers for carcinogens (potencies) and non-carcinogens (reference doses or concentrations). Cancer potencies express how much added cancer risk is associated with lifetime exposure to a unit dose of a chemical (presented as the additional cancer risk associated with an average daily dose of one milligram of a chemical per kilogram of bodyweight). Reference doses and concentrations are estimates of the daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects over a lifetime.

Risk assessment values or media quality standards can be used to evaluate the health risks posed by exposures to toxic chemicals. Media quality standards can be compared directly to information about the concentration of a chemical in the environment to identify potential health hazards. If a chemical concentration exceeds a relevant media quality standard, action to reduce environmental contamination or exposure is warranted. Unfortunately, there are relatively few chemicals with standards that define allowable concentrations in air, water, or food. More chemicals have risk assessment values, which can be combined with information about the dose of a chemical that someone receives to characterize health risks.

Scorecard includes all risk assessment values that have been developed by the state of California or by national regulatory agencies, such as the U.S. Environmental Protection Agency or the Agency for Toxic Substances and Disease Registry. A prioritization scheme determines which agency's RAV will be used if multiple agencies have developed RAVs for the same chemical. To ensure that RAVs are derived as consistently as possible, Scorecard adopts the agency with largest number of RAVs available as its priority source. California regulatory agencies have derived more cancer potency values and inhalation reference concentrations for chemical than any federal agency, so Scorecard preferentially adopts these RAVs. Other sources are then used if needed, ordered by the extent to which RAVs have undergone either scientific or regulatory review.

Scorecard risk assessment values are available from the website, along with a reference citation for each. Reference doses used by GHASP are listed in Table I-1. The sources for Table I-1 are state and federal agency references, as follows.

- **ATSDR:** Agency For Toxic Substances and Disease Registry, Minimum Risk Levels, atsdr1.atsdr.cdc.gov/mrls.html, December 2001.
- **CAPCOA:** California EPA and California Air Pollution Control Officers Association. *Air Toxics Hotspots Program Risk Assessment Guidance: Revised 1992 Risk Assessment Guidance*, Office of Environmental Health Hazard Assessment, California EPA, December 1994.
- **HEAST:** US EPA, Office of Research and Development. Health Effects Assessment Summary Tables. July 1997.
- **IRIS:** US EPA, National Center for Environmental Assessment, Integrated Risk Information System, www.epa.gov/iriswebp/iris/index.html.
- **OEHHA-CREL:** California EPA, Office of Environmental Health Hazard Assessment. *Air Toxics Hot Spots Program Risk Assessment Guidelines*, Part III: Technical Support Document "Determination of Noncancer Chronic Reference Exposure Levels," adopted and draft proposed Chronic Reference Exposure Levels (CRELs), www.oehha.ca.gov/air/chronic_rels/index.html, September 2002.
- **TRI:** US EPA, Office of Pollution Prevention and Toxics. *TRI Risk-Screening Environmental Indicators Version 2.0*, Technical Appendix A - Available Toxicity Data for TRI Chemicals of the RSEI User's Manual, www.epa.gov/opptintr/rsei/, February 2002.

These data were used as compiled by Environmental Defense at www.scorecard.org/chemical-profiles/def/rav_edf.html. For endpoints, see Scorecard at www.scorecard.org/health-effects/.

Table I-1: Non-cancer Chronic Disease Reference Concentrations and Relevant Endpoints

	Inhalation Reference Concentration (parts per billion)	Source of Inhalation Reference Concentration	Cardiovascular or Blood Toxicity	Developmental Toxicity	Endocrine Toxicity	Gastrointestinal or Liver Toxicity	Immunotoxicity	Kidney Toxicity	Neurotoxicity	Reproductive Toxicity	Respiratory Toxicity	Skin or Sense Organ Toxicity
1,1,1-Trichloroethane	180	OEHHA-CREL	✓	✓		✓				✓		✓
1,1,2,2-Tetrachloroethane	400	ATSDR		✓		✓					✓	
1,1,2-Trichloroethane	73	OEHHA-CREL	✓			✓		✓				✓
1,1-Dichloroethane	120	HEAST	✓									
1,1-Dichloroethylene	18	OEHHA-CREL	✓	✓		✓		✓		✓	✓	✓
1,2,4-Trimethylbenzene	1.2	TRI	✓								✓	
1,2-Dibromoethane	0.10	OEHHA-CREL		✓	✓	✓		✓	✓		✓	✓
1,2-Dichlorethane	99	OEHHA-CREL	✓	✓		✓		✓		✓	✓	✓
1,2-Dichloropropane	0.87	IRIS	✓		✓	✓		✓		✓	✓	✓
1,3-Butadiene	9.04	OEHHA-CREL	✓	✓		✓				✓	✓	✓
Acetaldehyde	5.0	OEHHA-CREL		✓				✓			✓	✓
Acetone	13,000	ATSDR	✓			✓		✓			✓	✓
Benzene	19	OEHHA-CREL	✓	✓	✓	✓	✓		✓		✓	✓
Bromomethane	1.3	OEHHA-CREL	✓	✓		✓		✓		✓	✓	✓
Carbon Tetrachloride	6.4	OEHHA-CREL	✓	✓	✓	✓		✓		✓	✓	✓
Chlorobenzene	220	OEHHA-CREL	✓	✓		✓		✓		✓		✓
Chloroform	61	OEHHA-CREL	✓	✓	✓	✓		✓		✓	✓	
Chloroprene	1.9	HEAST	✓	✓	✓	✓	✓			✓	✓	✓
Cyclohexane	780	TRI										
Ethylbenzene	460	OEHHA-CREL	✓	✓	✓	✓		✓		✓	✓	✓
Ethylene	17,000	OEHHA-CREL									✓	
Formaldehyde	2.4	OEHHA-CREL				✓	✓			✓	✓	✓
Isopropylbenzene	81	IRIS				✓						
m-Diethybenzene	46	OEHHA-CREL	✓	✓		✓	✓				✓	✓
m-Xylene	46	OEHHA-CREL	✓	✓		✓	✓				✓	✓
Methyl tert-butyl ether (MTBE)	2,200	OEHHA-CREL		✓		✓		✓				✓
Methylcyclohexane	750	HEAST										
Methylene Chloride	120	OEHHA-CREL	✓		✓	✓		✓		✓	✓	
n-Hexane	2,000	OEHHA-CREL		✓						✓	✓	✓
o-Xylene	46	OEHHA-CREL	✓	✓		✓	✓			✓	✓	✓
p-Xylene	46	OEHHA-CREL	✓	✓		✓	✓			✓	✓	✓
Propylene	1,700	OEHHA-CREL									✓	
Styrene	120	OEHHA-CREL	✓	✓	✓	✓	✓	✓		✓	✓	✓
Tetrachloroethylene	5.9	OEHHA-CREL	✓	✓		✓		✓		✓	✓	✓
Toluene	80	OEHHA-CREL	✓	✓		✓	✓	✓		✓	✓	✓
Trichloroethylene	110	OEHHA-CREL	✓	✓		✓		✓		✓	✓	✓
Trichlorofluoromethane	3,600	OEHHA-CREL	✓			✓					✓	✓
Vinyl Chloride	1.3	OEHHA-CREL	✓	✓		✓				✓	✓	✓
Acrolein	0.026	OEHHA-CREL	✓	✓		✓			✓		✓	✓
Acrylonitrile	2.3	OEHHA-CREL	✓	✓		✓		✓	✓	✓	✓	✓
Diesel particulates	5	IRIS	✓								✓	
Arsenic	0.0098	OEHHA-CREL	✓		✓	✓		✓	✓	✓	✓	✓
Chromium	0.047	TRI				✓	✓	✓		✓	✓	✓
Nickel	0.021	OEHHA-CREL	✓	✓			✓	✓	✓	✓	✓	✓
Ozone	92	CAPCOA	✓			✓	✓		✓		✓	✓

Sources are described in text.

J. Cumulative chronic disease hazard index for the Houston region.

For chemicals that cause non-cancer chronic health effects, risks are typically characterized using a measure called the hazard index. The hazard index for an individual chemical is calculated by dividing the exposure by the reference dose (see table I-1).

The cumulative chronic disease hazard index is the sum of the individual chemical hazard index values (see section B above for related discussion on the acute reference exposure level, which is calculated in an analogous manner). If the cumulative chronic disease hazard index is greater than 100%, an individual is at some risk of adverse health effects, because the cumulative dose exceeds a regulatory agency's estimate of the allowable daily intake. Note that non-cancer risk characterization does not generally involve quantitative predictions of how much an individual's risk of adverse effects is increased when a pollution exposure exceeds a reference dose.

Tables J-1 through J-4 summarizes the long-term average air toxic concentrations and non-cancer chronic disease hazard index values for the Houston region. These data are similar to those presented in section G, but include those pollutants for which a chronic exposure reference dose is available. The pollutants included in these tables are those monitored at a number of monitoring sites.

Table J-5 summarizes the same data for metals, which are only monitored at a few sites. The same issues discussed for tables G-7 and G-8 apply to these data.

The contribution of ozone to the chronic disease hazard index is about 1.08% per ppb of average exposure. Because ozone is of greater regulatory concern at peak daily and hourly values, environmental agencies do not make long-term average data as readily available. However, the long-term average is roughly in the range of 30 – 50 ppb. Since this method of analysis is not particularly sensitive to the exact values, these values have been used.

Acrylonitrile could be present at levels that would be a major non-cancer chronic disease concern. Individual samples taken by the Houston-Galveston Citizens Air Monitoring Project have found acrylonitrile at levels above 10 ppb. If these values reflect long-term averages (which is doubtful, but possible), then the contribution of acrylonitrile to the hazard index would be in the range of 400% for the relevant endpoints (see Table I-1). Because of these findings, further study of acrylonitrile levels in the Houston region is warranted.

Acrolein is present at levels that create a non-cancer chronic disease concern, but the actual level and geographic extent of exposure are uncertain. Only one study (see details in section B) has assessed average acrolein exposure levels in the Houston area. Based on the value reported in this study, acrolein would contribute about 275% to the hazard index for the relevant endpoints (see Table I-1). As noted in Section B, higher values of acrolein exposure have been measured in individual citizen samples.

Table J-1: East Ship Channel Area Long Term Air Toxic Concentrations and Non-cancer Chronic Disease Hazard Index Values

	Allendale (C120)		Clinton (C403)		Galena Park (C167)		Milby Park (C169)		Haden Rd.[1] (C603)	
	ppb	Index	ppb	Index	ppb	Index	ppb	Index	ppb	Index
1,1,1-Trichloroethane	0.094	0.1%	0.039	0.0%	0.018	0.0%	0.008	0.0%	0.040	0.0%
1,1,2,2-Tetrachloroethane			0.006	0.0%	0.005	0.0%	0.005	0.0%	0.005	0.0%
1,1,2-Trichloroethane	0.006	0.0%	0.006	0.0%	0.005	0.0%	0.005	0.0%	0.005	0.0%
1,1-Dichloroethane	0.006	0.0%	0.006	0.0%	0.005	0.0%	0.005	0.0%	0.006	0.0%
1,1-Dichloroethylene	0.008	0.0%	0.007	0.0%	0.008	0.0%	0.010	0.1%	0.009	0.1%
1,2,4-Trimethylbenzene	0.187	15.3%	0.136	11.1%	0.097	8.0%	0.063	5.2%	0.088	7.2%
1,2-Dibromoethane			0.006	5.5%	0.005	4.8%	0.005	4.8%	0.005	4.8%
1,2-Dichlorethane	0.012	0.0%	0.010	0.0%	0.008	0.0%	0.006	0.0%	0.018	0.0%
1,2-Dichloropropane	0.007	0.8%	0.005	0.6%	0.005	0.6%	0.005	0.6%	0.005	0.6%
1,3-Butadiene	1.423	15.7%	0.552	6.1%	0.476	5.3%	3.191	35.3%	0.420	4.6%
Acetaldehyde			1.610	32.2%					1.553	31.1%
Acetone			0.592	0.0%					0.509	0.0%
Benzene	0.983	5.2%	0.906	4.8%	1.503	8.0%	0.718	3.8%	0.913	4.9%
Bromomethane	0.011	0.9%	0.007	0.6%	0.006	0.5%	0.005	0.4%	0.006	0.5%
Carbon Tetrachloride	0.125	2.0%	0.081	1.3%	0.071	1.1%	0.076	1.2%	0.349	5.5%
Chlorobenzene	0.030	0.0%	0.010	0.0%	0.008	0.0%	0.009	0.0%	0.070	0.0%
Chloroform	0.046	0.1%	0.020	0.0%	0.030	0.1%	0.024	0.0%	0.041	0.1%
Chloroprene			0.005	0.3%	0.005	0.3%	0.005	0.3%	0.005	0.3%
Cyclohexane	0.324	0.0%	0.263	0.0%	0.270	0.0%	0.181	0.0%	0.530	0.1%
Ethylbenzene	0.194	0.0%	0.189	0.0%	0.175	0.0%	0.137	0.0%	0.137	0.0%
Ethylene	6.662	0.0%	5.201	0.0%	5.612	0.0%	4.829	0.0%	7.897	0.1%
Formaldehyde			3.968	162.5%					3.509	143.7%
Isopropylbenzene	0.029	0.0%	0.020	0.0%	0.015	0.0%	0.020	0.0%	0.060	0.1%
m-Diethybenzene										
m-Xylene	0.207	0.5%	0.238	0.5%	0.246	0.5%	0.129	0.3%	0.160	0.4%
Methyl tert-butyl ether (MTBE)	2.319	0.1%	2.349	0.1%	3.407	0.2%	3.042	0.1%	1.090	0.1%
Methylcyclohexane	0.235	0.0%	0.206	0.0%	0.186	0.0%	0.108	0.0%	0.149	0.0%
Methylene Chloride	0.143	0.1%	0.163	0.1%	0.077	0.1%	0.043	0.0%	0.101	0.1%
n-Hexane	0.746	0.0%	0.852	0.0%	0.878	0.0%	0.761	0.0%	0.728	0.0%
o-Xylene	0.233	0.5%	0.378	0.8%	0.203	0.4%	0.124	0.3%	0.146	0.3%
p-Xylene	0.413	0.9%	0.476	1.0%	0.492	1.1%	0.257	0.6%	0.320	0.7%
Propylene	4.479	0.3%	3.867	0.2%	3.754	0.2%	4.686	0.3%	6.238	0.4%
Styrene	0.121	0.1%	0.066	0.0%	0.075	0.0%	0.661	0.3%	0.171	0.1%
Tetrachloroethylene	0.033	0.6%	0.020	0.3%	0.015	0.3%	0.009	0.2%	0.015	0.3%
Toluene	1.167	1.5%	1.143	1.4%	1.208	1.5%	0.859	1.1%	1.065	1.3%
Trichloroethylene	0.010	0.0%	0.009	0.0%	0.011	0.0%	0.012	0.0%	0.015	0.0%
Trichlorofluoromethane	0.316	0.0%	0.284	0.0%	0.324	0.0%	0.277	0.0%	0.764	0.0%
Vinyl Chloride	0.025	1.9%	0.010	0.8%	0.012	1.0%	0.010	0.8%	0.052	4.2%

Source: See discussion in text.

Table J-2: West Ship Channel Area, Channnelview and Baytown Areas Long Term Air Toxic Concentrations and Non-cancer Chronic Disease Hazard Index Values

	Baytown (C148)		Channelview (C15)		Deer Park (C35)		San Jacinto (C166)		Shoreacres (C145)	
	ppb	Index	ppb	Index	ppb	Index	ppb	Index	ppb	Index
1,1,1-Trichloroethane	0.014	0.0%	0.182	0.1%	0.034	0.0%	0.008	0.0%	0.010	0.0%
1,1,2,2-Tetrachloroethane	0.005	0.0%	0.006	0.0%	0.005	0.0%	0.005	0.0%	0.005	0.0%
1,1,2-Trichloroethane	0.005	0.0%	0.005	0.0%	0.005	0.0%	0.007	0.0%	0.005	0.0%
1,1-Dichloroethane	0.005	0.0%	0.005	0.0%	0.005	0.0%	0.005	0.0%	0.005	0.0%
1,1-Dichloroethylene	0.010	0.1%	0.006	0.0%	0.008	0.1%	0.006	0.0%	0.006	0.0%
1,2,4-Trimethylbenzene	0.044	3.6%	0.090	7.4%	0.063	5.2%	0.020	1.7%	0.027	2.2%
1,2-Dibromoethane	0.005	4.8%	0.005	5.2%	0.005	4.8%	0.005	4.8%	0.005	4.8%
1,2-Dichlorethane	0.024	0.0%	0.033	0.0%	0.051	0.1%	0.245	0.3%	0.107	0.1%
1,2-Dichloropropane	0.005	0.6%	0.006	0.6%	0.007	0.8%	0.007	0.8%	0.005	0.6%
1,3-Butadiene	0.250	2.8%	0.491	5.4%	0.199	2.2%	0.421	4.7%	0.129	1.4%
Acetaldehyde			1.105	22.1%	1.215	24.3%				
Acetone			0.418	0.0%	0.611	0.0%				
Benzene	0.589	3.1%	0.942	5.0%	0.716	3.8%	1.354	7.2%	1.073	5.7%
Bromomethane	0.005	0.4%	0.006	0.5%	0.007	0.5%	0.005	0.4%	0.006	0.4%
Carbon Tetrachloride	0.059	0.9%	0.103	1.6%	0.076	1.2%	0.072	1.1%	0.066	1.0%
Chlorobenzene	0.029	0.0%	0.013	0.0%	0.019	0.0%	0.077	0.0%	0.011	0.0%
Chloroform	0.011	0.0%	0.030	0.1%	0.019	0.0%	0.029	0.1%	0.056	0.1%
Chloroprene	0.005	0.3%	0.005	0.3%	0.005	0.3%	0.005	0.3%	0.005	0.3%
Cyclohexane	0.589	0.1%	0.334	0.0%	0.223	0.0%	0.249	0.0%	0.306	0.0%
Ethylbenzene	0.058	0.0%	0.274	0.1%	0.080	0.0%	0.110	0.0%	0.121	0.0%
Ethylene	8.671	0.1%	7.154	0.0%	5.895	0.0%	9.878	0.1%	4.460	0.0%
Formaldehyde			3.806	155.8%	4.231	173.2%				
Isopropylbenzene	0.015	0.0%	0.049	0.1%	0.022	0.0%	0.015	0.0%	0.012	0.0%
m-Diethybenzene										
m-Xylene	0.086	0.2%	0.114	0.3%	0.079	0.2%	0.060	0.1%	0.094	0.2%
Methyl tert-butyl ether (MTBE)	0.577	0.0%	0.824	0.0%	0.822	0.0%	1.902	0.1%	0.517	0.0%
Methylcyclohexane	0.070	0.0%	0.176	0.0%	0.217	0.0%	0.061	0.0%	0.118	0.0%
Methylene Chloride	0.107	0.1%	0.107	0.1%	0.115	0.1%	0.088	0.1%	0.121	0.1%
n-Hexane	0.593	0.0%	0.568	0.0%	0.509	0.0%	0.863	0.0%	0.728	0.0%
o-Xylene	0.071	0.2%	0.125	0.3%	0.090	0.2%	0.055	0.1%	0.106	0.2%
p-Xylene	0.171	0.4%	0.227	0.5%	0.158	0.3%	0.120	0.3%	0.188	0.4%
Propylene	12.070	0.7%	6.981	0.4%	6.782	0.4%	23.243	1.3%	8.674	0.5%
Styrene	0.014	0.0%	0.264	0.1%	0.024	0.0%	0.062	0.0%	0.051	0.0%
Tetrachloroethylene	0.011	0.2%	0.016	0.3%	0.020	0.3%	0.012	0.2%	0.011	0.2%
Toluene	0.620	0.8%	0.948	1.2%	0.967	1.2%	0.708	0.9%	0.832	1.1%
Trichloroethylene	0.011	0.0%	0.019	0.0%	0.013	0.0%	0.008	0.0%	0.041	0.0%
Trichlorofluoromethane	0.276	0.0%	0.288	0.0%	0.279	0.0%	0.267	0.0%	0.278	0.0%
Vinyl Chloride	0.017	1.4%	0.054	4.3%	0.039	3.1%	0.093	7.4%	0.009	0.8%

Source: See discussion in text.

Table J-3: Houston Urban Area Long Term Air Toxic Concentrations and Non-cancer Chronic Disease Hazard Index Values

	Aldine (C8)		Bayland Park (C53)		NW Harris (C26)	
	ppb	Index	ppb	Index	ppb	Index
1,1,1-Trichloroethane	0.036	0.0%	0.015	0.0%	0.017	0.0%
1,1,2,2-Tetrachloroethane	0.005	0.0%	0.005	0.0%	0.005	0.0%
1,1,2-Trichloroethane	0.007	0.0%	0.005	0.0%	0.006	0.0%
1,1-Dichloroethane	0.006	0.0%	0.005	0.0%	0.006	0.0%
1,1-Dichloroethylene	0.009	0.1%	0.008	0.1%	0.019	0.1%
1,2,4-Trimethylbenzene	0.116	9.5%	0.069	5.7%	0.025	2.0%
1,2-Dibromoethane	0.005	4.8%	0.005	4.8%	0.005	4.8%
1,2-Dichlorethane	0.011	0.0%	0.005	0.0%	0.006	0.0%
1,2-Dichloropropane	0.007	0.8%	0.005	0.6%	0.005	0.6%
1,3-Butadiene	0.176	2.0%	0.094	1.0%	0.045	0.5%
Acetaldehyde			1.118	22.4%		
Acetone			0.784	0.0%		
Benzene	0.668	3.6%	0.484	2.6%	0.436	2.3%
Bromomethane	0.011	0.9%	0.006	0.4%	0.005	0.4%
Carbon Tetrachloride	0.077	1.2%	0.060	0.9%	0.059	0.9%
Chlorobenzene	0.009	0.0%	0.007	0.0%	0.029	0.0%
Chloroform	0.019	0.0%	0.010	0.0%	0.007	0.0%
Chloroprene	0.005	0.3%	0.005	0.3%	0.005	0.3%
Cyclohexane	0.150	0.0%	0.077	0.0%	0.244	0.0%
Ethylbenzene	0.498	0.1%	0.095	0.0%	0.100	0.0%
Ethylene	4.567	0.0%	3.152	0.0%	2.045	0.0%
Formaldehyde			3.402	139.3%		
Isopropylbenzene	0.034	0.0%	0.008	0.0%	0.008	0.0%
m-Diethybenzene						
m-Xylene	1.458	3.2%	0.101	0.2%	0.115	0.3%
Methyl tert-butyl ether (MTBE)	1.105	0.1%	0.715	0.0%	0.278	0.0%
Methylcyclohexane	0.377	0.1%	0.083	0.0%	0.254	0.0%
Methylene Chloride	0.090	0.1%	0.069	0.1%	0.042	0.0%
n-Hexane	0.473	0.0%	0.309	0.0%	0.273	0.0%
o-Xylene	1.537	3.3%	0.103	0.2%	0.194	0.4%
p-Xylene	2.915	6.3%	0.201	0.4%	0.229	0.5%
Propylene	3.008	0.2%	1.848	0.1%	1.309	0.1%
Styrene	0.049	0.0%	0.017	0.0%	0.163	0.1%
Tetrachloroethylene	0.014	0.2%	0.024	0.4%	0.010	0.2%
Toluene	1.143	1.4%	0.989	1.2%	0.611	0.8%
Trichloroethylene	0.013	0.0%	0.007	0.0%	0.017	0.0%
Trichlorofluoromethane	0.304	0.0%	0.283	0.0%	0.275	0.0%
Vinyl Chloride	0.013	1.0%	0.008	0.6%	0.010	0.8%

Source: See discussion in text.

Table J-4: Brazoria and Galveston Counties Long Term Air Toxic Concentrations and Non-cancer Chronic Disease Hazard Index Values

	Clute (C11)		Texas City (C147)		Texas City (C100)		Galveston (C34)	
	ppb	Index	ppb	Index	ppb	Index	ppb	Index
1,1,1-Trichloroethane								
1,1,2,2-Tetrachloroethane								
1,1,2-Trichloroethane								
1,1-Dichloroethane								
1,1-Dichloroethylene								
1,2,4-Trimethylbenzene								
1,2-Dibromoethane								
1,2-Dichlorethane								
1,2-Dichloropropane								
1,3-Butadiene								
Acetaldehyde								
Acetone								
Benzene	0.509	2.7%	1.189	6.3%	0.830	4.4%	0.266	1.4%
Bromomethane	0.009	0.7%	0.006	0.4%	0.007	0.5%	0.006	0.5%
Carbon Tetrachloride	0.102	1.6%	0.062	1.0%	0.103	1.6%	0.067	1.1%
Chlorobenzene	0.039	0.0%	0.008	0.0%	0.020	0.0%	0.010	0.0%
Chloroform	0.020	0.0%	0.008	0.0%	0.038	0.1%	0.010	0.0%
Chloroprene	0.005	0.3%	0.005	0.3%	0.005	0.3%	0.005	0.3%
Cyclohexane	1.408	0.2%	0.230	0.0%	0.186	0.0%	0.063	0.0%
Ethylbenzene	0.079	0.0%	0.192	0.0%	0.118	0.0%	0.039	0.0%
Ethylene	23.206	0.1%	5.006	0.0%	4.086	0.0%	1.484	0.0%
Formaldehyde								
Isopropylbenzene								
m-Diethybenzene	0.008	0.0%	0.029	0.1%	0.014	0.0%	0.010	0.0%
m-Xylene	0.059	0.1%	0.159	0.4%	0.106	0.2%	0.030	0.1%
Methyl tert-butyl ether (MTBE)	0.391	0.0%	0.585	0.0%	0.437	0.0%	0.137	0.0%
Methylcyclohexane	0.071	0.0%	0.217	0.0%	0.172	0.0%	0.071	0.0%
Methylene Chloride	0.891	0.8%	0.088	0.1%	0.175	0.2%	0.066	0.1%
n-Hexane	0.255	0.0%	0.865	0.0%	0.602	0.0%	0.213	0.0%
o-Xylene	0.062	0.1%	0.142	0.3%	0.111	0.2%	0.044	0.1%
p-Xylene	0.117	0.3%	0.319	0.7%	0.213	0.5%	0.059	0.1%
Propylene	3.253	0.2%	4.175	0.2%	3.888	0.2%	1.174	0.1%
Styrene	0.042	0.0%	0.027	0.0%	0.033	0.0%	0.016	0.0%
Tetrachloroethylene								
Toluene	0.483	0.6%	0.823	1.0%	0.552	0.7%	0.712	0.9%
Trichloroethylene	0.052	0.1%	0.007	0.0%	0.010	0.0%	0.018	0.0%
Trichlorofluoromethane	0.291	0.0%	0.273	0.0%	0.288	0.0%	0.277	0.0%
Vinyl Chloride	0.064	5.1%	0.009	0.7%	0.023	1.8%	0.008	0.6%

Source: See discussion in text.

Table J-5: Houston Area Long Term Air Toxic Concentrations and Non-cancer Chronic Disease Hazard Index Values, Metals Using PM_{10} Monitors

PM_{10} Monitor Values	Clinton (C403)		Deer Park (C35)	
	ppb	Index	ppb	Index
Arsenic	0.0109	111%	0.0105	107%
Chromium	0.0016	3%	0.0007	1%
Nickel	0.0016	8%	0.0016	8%

Source: See discussion in text.

Table J-6: Houston Area Long Term Air Toxic Concentrations and Non-cancer Chronic Disease Hazard Index Values, Metals Using $PM_{2.5}$ Monitors

$PM_{2.5}$ Monitor Values	Haden Rd.[1] (C603)		Channelview (C15)		Aldine (C8)		Bayland Park (C53)	
	ppb	Index	ppb	Index	ppb	Index	ppb	Index
Arsenic	0.0003	3%	0.0004	4%	0.0009	9%	0.0007	7%
Chromium	0.0005	1%	0.0005	1%	0.0005	1%	0.0003	1%
Nickel	0.0015	7%	0.0009	4%	0.0006	3%	0.0004	2%

Source: See discussion in text.

Table J-7: Diesel Non-cancer Disease Hazard Index Values

Site	Measured Diesel $PM_{2.5}$ (ug/m^3)	Percent of $PM_{2.5}$ Sample	Long-term[1] Total $PM_{2.5}$ (ug/m^3)	Calculated Diesel $PM_{2.5}$ (ug/m^3)	Non-cancer Hazard Index
Galveston	0.5[2]	4%	10.1	0.4	8%
LaPorte	1.1[3]	9%	12.3	1.1	22%
Haden Rd. (HRM-3)	2.0[3]	12%	15.0	1.8	36%
Clinton Dr.	3.7[2]	17%	13.4	2.3	46%
Aldine	1.6[3]	11%	12.6	1.3	26%

[1] Long-term average $PM_{2.5}$ calculated using 2000-2002 data, except at Haden Road where 2002 data were not available, so 1999-2001 data were used.

[2] Diesel $PM_{2.5}$ measurements made during 1997-1998.

[3] Diesel $PM_{2.5}$ measurements made during August-September 2000.

Source: Fraser, M.P., Z. W. Yue and B. Buzco, "Organic Speciation and Source Apportionment of Fine PM during TexAQS 2000" (November 2002 Presentation).

Table J-8: Summary of Houston Region Long Term Air Toxic Concentrations and Non-cancer Disease Hazard Index Values

	Low Urban		High Urban		Low Industrial		High Industrial	
	ppb	Index	ppb	Index	ppb	Index	ppb	Index
Metals (PM_{10})								
Arsenic	0.0100	100%	0.0100	100%	0.0100	100%	0.0100	100%
Chromium	0.0007	1%	0.0007	1%	0.0007	1%	0.0016	3%
Nickel	0.0016	8%	0.0016	8%	0.0016	8%	0.0016	8%
Acrolein	0.0725	275%	0.0725	275%	0.0725	275%	0.0725	275%
Ozone	30.0000	32%	50.0000	54%	50.0000	54%	50.0000	54%
Diesel particulates		8%		25%		25%		50%
1,1,1-Trichloroethane	0.015	0.0%	0.036	0.0%	0.010	0.0%	0.182	0.1%
1,1,2,2-Tetrachloroethane	0.005	0.0%	0.005	0.0%	0.005	0.0%	0.006	0.0%
1,1,2-Trichloroethane	0.005	0.0%	0.007	0.0%	0.005	0.0%	0.007	0.0%
1,1-Dichloroethane	0.005	0.0%	0.019	0.1%	0.005	0.0%	0.006	0.0%
1,1-Dichloroethylene	0.008	0.1%	0.009	0.1%	0.006	0.0%	0.010	0.1%
1,2,4-Trimethylbenzene	0.069	5.7%	0.025	2.0%	0.020	1.7%	0.187	15.3%
1,2-Dibromoethane	0.005	4.8%	0.005	4.8%	0.005	4.8%	0.006	5.5%
1,2-Dichlorethane	0.005	0.0%	0.011	0.0%	0.006	0.0%	0.245	0.3%
1,2-Dichloropropane	0.005	0.6%	0.007	0.8%	0.005	0.6%	0.007	0.8%
1,3-Butadiene	0.094	1.0%	0.176	2.0%	0.129	1.4%	3.191	35.3%
Acetaldehyde	1.118	22.4%	1.118	22.4%	1.105	22.1%	1.610	32.2%
Acetone	0.784	0.0%	0.784	0.0%	0.418	0.0%	0.784	0.0%
Benzene	0.266	1.4%	0.668	3.6%	0.509	2.7%	1.503	8.0%
Bromomethane	0.005	0.4%	0.011	0.9%	0.005	0.4%	0.011	0.9%
Carbon Tetrachloride	0.059	0.9%	0.077	1.2%	0.059	0.9%	0.349	5.5%
Chlorobenzene	0.007	0.0%	0.029	0.0%	0.008	0.0%	0.077	0.0%
Chloroform	0.019	0.0%	0.007	0.0%	0.008	0.0%	0.056	0.1%
Chloroprene	0.005	0.3%	0.005	0.3%	0.005	0.3%	0.005	0.3%
Cyclohexane	0.007	0.0%	0.063	0.0%	0.181	0.0%	1.408	0.2%
Ethylbenzene	0.039	0.0%	0.498	0.1%	0.039	0.0%	0.498	0.1%
Ethylene	1.484	0.0%	4.567	0.0%	4.086	0.0%	23.206	0.1%
Formaldehyde	3.402	139.3%	3.402	139.3%	3.509	143.7%	4.231	173.2%
Isopropylbenzene	0.008	0.0%	0.034	0.0%	0.012	0.0%	0.060	0.1%
m-Diethybenzene	0.010	0.0%	0.010	0.0%	0.008	0.0%	0.029	0.1%
m-Xylene	0.030	0.1%	1.458	3.2%	0.059	0.1%	1.458	3.2%
Methyl tert-butyl ether (MTBE)	0.137	0.0%	1.105	0.1%	0.391	0.0%	3.407	0.2%
Methylcyclohexane	0.071	0.0%	0.377	0.1%	0.061	0.0%	0.235	0.0%
Methylene Chloride	0.066	0.1%	0.090	0.1%	0.043	0.0%	0.891	0.8%
n-Hexane	0.213	0.0%	0.473	0.0%	0.255	0.0%	0.878	0.0%
o-Xylene	0.044	0.1%	1.537	3.3%	0.055	0.1%	1.537	3.3%
p-Xylene	0.059	0.1%	2.915	6.3%	0.117	0.3%	2.915	6.3%
Propylene	1.174	0.1%	3.008	0.2%	3.253	0.2%	23.243	1.3%
Styrene	0.016	0.0%	0.163	0.1%	0.014	0.0%	0.661	0.3%
Tetrachloroethylene	0.010	0.2%	0.024	0.4%	0.009	0.2%	0.033	0.6%
Toluene	0.611	0.8%	1.143	1.4%	0.483	0.6%	1.208	1.5%
Trichloroethylene	0.007	0.0%	0.017	0.0%	0.007	0.0%	0.052	0.1%
Trichlorofluoromethane	0.275	0.0%	0.304	0.0%	0.267	0.0%	0.324	0.0%
Vinyl Chloride	0.008	0.6%	0.013	1.0%	0.009	0.8%	0.093	7.4%
CUMULATIVE INDEX BY TOXICITY ENDPOINT (BASED ON AVAILABLE DATA)								
Cardiovascular or Blood		435%		489%		472%		577%
Developmental		316%		334%		318%		394%
Endocrine		108%		111%		109%		121%
Gastrointestinal or Liver		559%		599%		587%		686%
Immunotoxicity		183%		221%		211%		261%
Kidney		295%		296%		292%		354%
Neurotoxicity		421%		445%		445%		451%
Reproductive		254%		266%		258%		348%
Respiratory		603%		657%		644%		793%
Skin or Sense Organ		589%		629%		617%		725%

Source: See tables J-1 through J-7; GHASP selected highest and lowest value for each pollutant to capture all possible values.

K. Additional data are needed, especially for acrolein, acrylonitrile, crotonaldehyde and PAHs.

Although screening for mutagenic effects and metabolic relationships suggests that crotonaldehyde may be a carcinogen, there has been only one animal study of crotonaldehyde and no human studies.

There is no routine monitoring for acrolein, acrylonitrile, or PAHs by any government agency for the Houston region. Although these chemicals are among the air toxics considered by the US Environmental Protection Agency to be of significant concern, the air pollution monitoring technologies used for routine air quality monitoring in the Houston region are either not capable of measuring these pollutants, or not used in such a way that these chemicals are detected.

Two data sources were found for PAHs, one for acrolein and one for acrylonitrile. For PAHs, the data from Park, Wade, and Sweet were used and the Swartz data were not used.

- PAHs: Park, June-Soo, Terry L. Wade, and Stephen Sweet, “Atmospheric distribution of polycyclic aromatic hydrocarbons and deposition to Galveston Bay, Texas, USA.” *Atmospheric Environment* 35 (2001) 3241-3249.
- PAHs: Dr. Erick Swartz of the US Environmental Protection Agency provided data for six 12-hour samples from the LaPorte monitoring site collected in August and September 2000. Because PAH analysis and synthesis requires scientific steps that were beyond the scope of this project, these data were not used.
- Acrolein: Dr. Daniel Riemer, University of Miami, Rosenstiel School of Marine and Atmospheric Science, Division of Marine and Atmospheric Chemistry, provided an unpublished data set collected at the La Porte Airport on 8/19/2000 – 9/12/2000 as part of TexAQS 2000. The data represent 5 minute average values collected approximately twice an hour. This data set is used in this analysis because it is the only publicly-available measurement of acrolein for Houston besides individual samples. Because it represents only a month of sampling, its results should be considered with that limitation in mind.
- Acrylonitrile: No scientific data sets were identified that included acrylonitrile. However, several air pollution samples gathered by the Houston-Galveston Citizens Air Monitoring Project did measure acrylonitrile at levels that would be significant for long-term exposure – typically 10 ppb. Scorecard.org used US EPA modeled exposure estimates to determine that acrylonitrile could cause an added cancer risk of 14 per one million, which reflects an average exposure of 0.1 ppb (about one percent of H-GCAMP measured values). Using the lowest detected values of acrylonitrile in available H-GCAMP samples (10 ppb), the added cancer risk due to acrylonitrile is 1,336 per million. Since this added cancer risk is based on extrapolation from only a few samples, it was not included in figure 2.

Clearly, none of these data sources are adequate to characterize long-term exposures. Nevertheless, in the absence of other monitoring data and when corroborated by findings endorsed by the US Environmental Protection Agency, then these data are sufficient to raise concerns about the potential health effects of these pollutants in the Houston area.

The risk analysis presented in this report combines available monitoring data with what is currently known about the toxicity of air pollutants found in the Houston region. In addition to the issues with specific chemicals (as described above), there are other uncertainties that indicate what questions might better be answered with further research.

Regulatory agencies use health-protective assumptions to compensate for the difficulty of obtaining the "perfect" set of health data, and these assumptions may result in overestimates of risk. For example, regulatory agencies sometimes assume that animal toxicity test results are predictive of human responses, and that there is some risk of a carcinogenic response at even extremely low doses. These health-protective assumptions are often criticized by chemical defenders as leading to biased risk assessments.

However, other uncertainties that are currently ignored in conventional risk assessment may result in underestimating health risks. Risk assessment values are derived based on the assumption that people are exposed to a single chemical at a time, and that there is no significant interaction between chemicals that heightens the probability of adverse outcomes. Variations in susceptibility to a toxic chemical between people are often ignored, even though it is known that factors such as health status or genetic characteristics can greatly affect how someone responds to chemical exposure. Risk assessments usually don't take into account the special vulnerabilities of children. These and other important factors that could affect health outcomes are often ignored because there are not sufficient data to develop these factors into mathematical models.

L. Figure 3: Fine Particulates in the Houston Region

Unlike ozone precursors, there is no comprehensive inventory for sources of fine particulates in the Houston region. GHASP constructed an analysis of recent studies to suggest the primary sources of particulates, and awaits further studies to explore these questions in more detail.

The most comprehensive summary of information regarding fine particulates in the Houston region is: David Allen, "Particulate Matter Concentrations, Compositions, and Sources in Southeast Texas: State of the Science and Critical Research Needs, Texas Environmental Research Consortium (December, 2002).

However, based on data collected by Matt Fraser and others at Rice University, quite a bit can be said about the sources of fine particulates ($PM_{2.5}$). Short-term studies indicate the relative importance of various source types (diesel combustion, road dust, etc.).

These data are presented by mass and as a percent of total sample (table L-1). Because the vast majority of sulfur emissions are from industrial sources, GHASP assumed that 75% of ammonium sulfate particles are formed as a result of industrial emissions.

A relatively high percentage of emissions at Galveston cannot be attributed to any source. This is likely to be a mixture of marine particulates (minerals, etc.) and particulates from distant sources such as power plants in the southeastern United States. Particulates from distant sources cannot be easily matched to a source type because of chemical evolution that occurs over time.

Based on the percentages from Fraser's research and long-term average particulate levels available at the time of analysis, the long-term average mass of each source type was estimated by GHASP (table L-2).

Figure 3 in the main report also presents a value of 11.0 μg/m^3 for Conroe, based on 2002 data.

Table L-1: Sources of $PM_{2.5}$ Pollution in the Houston Region

	Galveston[3]		LaPorte[4]		Haden Rd[4]		Aldine[4]		Clinton[3]	
	μg/m^3	%	μg/m^3	%	μg/m^3	%	μg/m^3	%	μg/m^3	%
Total Organics	*1.9*	*14%*	*3.9*	*32%*	*7.6*	*46%*	*8.4*	*56%*	*12.4*	*57%*
Diesel	0.5	4%	1.1	9%	2	12%	1.6	11%	3.7	17%
Gas	0.5	4%	0.9	7%	2.1	13%	3.4	23%	2.8	13%
Road dust	0.1	1%	0.2	2%	0.8	5%	0.1	1%	2.3	11%
Meat cooking	0.7	5%	1.3	11%	1	6%	2.5	17%	1.3	6%
Wood smoke	0.1	1%	0.2	2%	0.7	4%	0.1	1%	0.3	1%
Vegetative wax	-	0%	0.1	1%	0.8	5%	0.6	4%	0.5	2%
Fuel oil	-	0%	0.1	1%	0.2	1%	0.1	1%	1.5	7%
Industry	[1]	29%	[1]	38%	[1]	30%	[1]	33%	[1]	29%
Other	[2]	57%	[2]	30%	[2]	24%	[2]	11%	[2]	14%

Sources and notes:

[1] Industry estimated as 75% of ammonium sulfate, which is formed in the atmosphere from sulfur and ammonia. Because there is a large amount of ammonia in the Houston area atmosphere, sulfur emissions are the controlling component. Most sulfur emissions are from industry.

[2] Other represents balance of fine particulates.

[3] Diesel $PM_{2.5}$ measurements made during 1997-1998.

[4] Diesel $PM_{2.5}$ measurements made during August-September 2000.

Source: Fraser, M.P., Z. W. Yue and B. Buzco, "Organic Speciation and Source Apportionment of Fine PM during TexAQS 2000" (November 2002 Presentation).

Table L-2: Estimate of $PM_{2.5}$ Pollution Sources in the Houston Region

Monitoring data	Galveston[3] $\mu g/m^3$	LaPorte[4] $\mu g/m^3$	Haden Rd[4] $\mu g/m^3$	Aldine[4] $\mu g/m^3$	Clinton[3] $\mu g/m^3$
1999			16.2	18.1	17.1
2000	11.5	12.3	15.4	14.5	13.1
2001	10.2		13.5	12.6	14.8
2002	8.5			10.8	12.2
Average[1]	10.1	12.3	15.0	12.6	13.4

Source estimate	%	$\mu g/m^3$	%	$\mu g/m^3$	%	$\mu g/m^3$	%	$\mu g/m^3$	%	$\mu g/m^3$
Industry[2]	29%	2.9	38%	4.7	30%	4.5	33%	4.2	29%	3.9
Gas[2]	4%	0.4	7%	0.9	13%	1.9	23%	2.9	13%	1.7
Diesel[2]	4%	0.4	9%	1.1	12%	1.8	11%	1.3	17%	2.3
Meat cooking[2]	5%	0.5	11%	1.3	6%	0.9	17%	2.1	6%	0.8
Minor[3]	1%	0.1	5%	0.6	15%	2.3	6%	0.8	21%	2.8
Other[2]	57%	5.7	30%	3.7	24%	3.6	11%	1.4	14%	1.8

Sources and notes:

[1] Most recent three-year data available at time of analysis. PM2.5 data obtained from TCEQ and EPA sources, except for LaPorte which is from Fraser, Yue and Buzco.

[2] Percentage from Table L-1, mass based on percentage of long-term average for monitor.

[3] Percentage from Table L-1, including road dust, wood smoke, vegetative wax, and fuel oil, mass based on percentage of long-term average for monitor.

M. Scientists informally estimate that . . . more than half . . . of formaldehyde forms in the atmosphere from . . . industrial organic chemicals.

This statement is primarily based on informal conversations with a number of scientists involved in the Texas Air Quality Study. There has not been a study with a goal of accurately quantifying the sources of ambient formaldehyde.

However, one study generalizes that, "Results reported here indicate that measured petrochemical ethene and propene levels were alone sufficient to explain the highest [formaldehyde] and ozone levels measured in several Houston area plumes, including levels over 30 and 200 ppbv, respectively. No evidence was found for strong direct emissions of [formaldehyde]." Wert, B.P. et al, "Signatures of Terminal Alkene Oxidation in Airborne Formaldehyde Measurements During TexAQS 2000," (National Center for Atmospheric Research, 2003). Based on these conclusions, "more than half" might be an understatement.

N. Texas environmental officials conservatively estimate that industrial organic chemical pollution is six times higher than represented in reports from industry.

In its December 2002 rulemaking, the Texas Commission on Environmental Quality relied on a modified inventory of highly-reactive volatile organic compounds (HRVOCs) to represent actual emissions of HRVOCs in the Houston region. According to the TCEQ, 78% of the HRVOC emissions included in its inventory were added to account for the gap between observed HRVOC levels and reported emissions (TCEQ, Rule Log Numbers 2002-046b-115-AI and 2002-046d-115-AI).

This analysis is derived from the Accelerated Science Evaluation sponsored by the TCEQ.

> **Finding 6: Industrial hydrocarbon emissions are significantly underestimated.** Measurements of the ratios of hydrocarbons to NOx in the industrial plumes were consistently factors of 2-15, and in some isolated instances even a factor of 50 or more higher, than the ratios reported in the inventories. Mass balance calculations suggest that the NOx inventory is in reasonable agreement with observations and that the main reason for the high ratios is underestimation of hydrocarbon emissions. Estimates of the emissions of alkanes, alkenes and aromatics all appear to be low. In most observations, alkenes contribute the bulk of the reactivity; however, in some plumes alkanes or aromatics contribute the bulk of the reactivity.
>
> Source: Science Synthesis Committee, “Accelerated Science Evaluation of Ozone Formation in the Houston/Galveston Area,” November 13, 2002.)

Essentially, it is a consensus of the scientific community that hydrocarbon emissions are underestimated by a factor of 2-15.

The most specific analysis of underreporting by the TCEQ found that olefins (a class of hydrocarbons, roughly equivalent to HRVOCs) were underreported by a range of 1.2 to 14.1 across the industrial areas of east Harris and Chambers counties (see Table N-1).

Table N-1: TCEQ Analysis of Reported and Inferred Olefin Emissions
(Based on long-term automated gas chromatograph data)

Source Cluster	Reported emissions (tons/day)	Inferred emissions (tons/day)	Factor
West Ship Channel 2	1.48	3.13	2.1
West Ship Channel 1	1.22	1.51	1.2
West Central Ship Channel	1.21	2.78	2.3
East Central Ship Channel	0.66	5.00	7.6
East Ship Channel	8.10	47.50	5.9
Baytown	2.81	39.50	14.1
Channelview	3.16	5.95	1.9
Mont Belvieu	1.75	3.88	2.2
Bayport	0.92	11.90	12.9
Total	**21.31**	**121.15**	**5.7**

Source: TCEQ, Technical Support Document, Part 3, December 13, 2002 (Table 3-2).

Although the TCEQ has not formally extended its emission inventory adjustments to other VOC species (non-HRVOCs), there is good indication that similar reporting problems exist for most industrial VOC emissions. Reflecting on the findings presented in Table N-1 above, the TCEQ commented, “Also note that in this analysis, emission adjustments have only been calculated for light olefins, but there are good indications that similar adjustments will be needed for many other VOCs as well.” (TCEQ, Technical Support Document, Part 3, December 13, 2002).

In addition to independent scientists and state regulators, an analysis of data collected by an industry monitoring consortium found similar results. (Albert Hendler, Walt Crow, and Sumedha Takiar, “Comparison of VOC/NOx Emission Ratios with Ambient Measurements,” URS Corporation, 2003.)

While the clarity, specificity and scientific implications of these findings are new, the same general information has been available for at least a decade.

> "Substantially elevated mixing ratios of highly reactive alkenes have been a persistent feature of the Houston area for an extended period of time. Previous studies in the Houston area in 1976 (Gulf Coast Oxidant Study), 1977 (Houston Area Oxidants Study), and in 1993 (Coastal Oxidant Assessment for Southeast Texas and Gulf of Mexico Air Quality Study have all found very high median mixing ratios of alkenes at sampling sites in the Ship Channel area. These studies suggest that mixing ratios of propene and ethene in particular have been strongly elevated in the Ship Channel region for over twenty years, beginning with some of the first measurements showing a Houston ozone exceedence problem. More recently, 24-hour- integrated canister VOC samples taken twice a week since 1997 at various locations along the Ship Channel have shown median mixing ratios of propene (ca. 4 ppbv) and ethene (ca. 12 ppbv) sufficient to dominate VOC reactivity, qualitatively consistent with the findings reported here."
>
> Source: Ryerson, T. B. et al, "Effect of petrochemical industrial emissions of reactive alkenes and NOx on tropospheric ozone formation in Houston, TX," (Aeronomy Laboratory, National Oceanic and Atmospheric Administration, 2003, citations in original omitted).

Although this information has been available for years (to those with the requisite understand and resources to analyze it), neither the companies responsible for this pollution nor state regulators made any public statements suggesting that there might be major problems with emissions reporting by industrial sources until after the findings were presented by independent scientists associated with the Texas Air Quality Study 2000.

O. Figure 4: Sources of Ozone-Forming Pollutants (VOCs)

Historically, scientific and regulatory presentations of volatile organic compound (VOC) emissions data have been provided in tons per day, and have included emissions estimates covering a large region. For example, the University of Houston recently summarized data used in its air quality model for Houston. Of the 5,035 tons per day of VOCs included in the model, over 80% of these emissions (by weight) are from biogenic sources (trees and other vegetation) and about 60% of these emissions (by weight) are from outside the eight-county Houston region. Nevertheless, it would be erroneous to conclude that Houston's ozone problem is caused by trees outside the region.

When viewed in the context of other scientific findings, in fact, the opposite is true: Houston's ozone problem is primarily caused by industrial sources in and near the Houston region.

- Not all VOCs are created equal – some VOCs form far more ozone on a pound-for-pound basis than others. This concept is known as "reactivity." There are several different ways of measuring reactivity, but essentially it represents the total capacity of a given amount of VOCs to create ozone.
- Location matters – VOCs that are emitted near major sources of nitrogen oxides (NOx) create more ozone than those emitted farther away. Industrial areas are

> almost always the sources of ozone plumes and pools of ozone. While pollution from urban sources and other nearby sources can influence the level and extent of ozone pollution, ozone peaks are almost always downwind of the Houston Ship Channel or one of the other industrial areas in the Houston region.

Several recent studies have verified that in the major ozone-producing regions, the types of VOCs that most strongly influence ozone production are those associated with industrial activity.

One study looked at several years of data collected by the state at the Clinton Drive air quality monitor. An analysis of these data indicated that most of the VOCs could be associated with one of fifteen source types. As indicated in Table O-1, about three-quarters of the reactivity measured at this site is associated with industrial activity. The remaining sites are primarily traffic (whether gasoline or diesel). Less than 10% of VOC reactivity in this area can be associated with biogenic sources.

Dr. Peter Daum of Brookhaven National Laboratory has taken a different approach. He compared Houston to four other cities where his laboratory has conducted extensive air quality research. His general findings are that Houston's air includes a substantial amount of hydrocarbons that are in excess of reported emissions, and that are primarily responsible for rapid ozone formation, and for ozone reaching such large peak levels.

Table O-1: Sources of Ozone-Forming VOCs
Measured by reactivity at the Clinton Drive monitor

Estimated Source Type		Total Reactivity (avg. percent)	Industrial	Other	Biogenic
1	Industrial flares	5	5		
2	Industrial aromatic hydrocarbons #1	1	1		
3	Motor vehicle	10		10	
4	Industrial light olefins	16	16		
5	Evaporative emissions/background	1	0.5	0.5	
6	Solvent use	2	2		
7	Industrial pentene source	18	18		
8	Industrial aromatic hydrocarbons #2	13	13		
9	Butadiene sources	8	8		
10	Evaporative emissions/solvents	2	1	1	
11	Accumulated emissions and natural gas	1	1		
12	Heavy aromatic sources	2		2	
13	Diesel	3		3	
14	Biogenic with outliers from industry	8			8
15	Industrial butane source	10	10		
	Total	**100%**	**75.5%**	**16.5%**	**8.0%**

Source: Sonoma Technology, *Exploratory Source Apportionment of Houston's Clinton Drive Auto-GC 1998-2001 Data* (2003). See Table 6-1.

P. Figure 4: Sources of Ozone-Forming Pollutants (NOx)

The sources for the data in the illustration are several different reports. Each of these reports was the most up-to-date source of data for each category available at the time the graphic was generated (see Table P-1).

The Texas Commission on Environmental Quality has also provided county-by-county estimates of emissions by category (see Table P-2). In the case of traffic emissions, these are for a representative day and are not exactly the same type of estimate as provided in Table P-1. As can be noted, these numbers are slightly different than those illustrated in Table P-1. While emission estimates vary by method and the purpose for which they are intended, the overall pattern is similar between the two totals.

Table P-1: Average Daily Nitrogen Oxide Emissions by Source Category
Most Recent Data

	Tons per Day	Percent	Reference
Industry	472.5	50%	Texas Commission on Environmental Quality, Year 2000 Emission Inventory
Traffic	276.8	30%	Houston-Galveston Area Council, Conformity Determination (Year 2000 w/o 55 mph speed limit)
Other	188.0	20%	Texas Commission on Environmental Quality, December 2001 SIP (based on 2002 ROP Budget)
Total	**937.3**	**100%**	

Table P-2: Daily Nitrogen Oxide Emissions by Source Category and County
(tons per day)

	Industry	Traffic	Other	Total	Percent
Brazoria	59.5	11.8	19.0	90.4	10%
Chambers	25.4	5.7	6.3	37.3	4%
Fort Bend	103.1	13.8	14.2	131.1	14%
Galveston	89.7	12.8	13.2	115.7	13%
Harris	186.2	177.0	113.9	477.1	52%
Liberty	6.6	4.6	7.0	18.2	2%
Montgomery	13.7	15.8	8.7	38.3	4%
Waller	5.4	4.2	5.2	14.8	2%
Total	**489.7**	**245.7**	**187.5**	**922.9**	
Percent	53%	27%	20%		

Source: Texas Commission on Environmental Quality Technical Analysis Division, December 2002 revision to the State Implementation Plan, Attachment 3: Emissions Inventory Development and Modeling for the August 25-September 1, 2000 Episode (November 15, 2002). Industry: Figure 15. Mobile: Table 11. Other: Figures 35 and 37.

Q. Grandfathered plants are finally required to obtain permits and install modest pollution control equipment.

Over the course of three legislative sessions (1997, 1999, and 2001), the Texas Legislature finally addressed the problem of grandfathered plants or facilities. A grandfathered facility is one that existed at the time the legislature created the Texas Clean Air Act (TCAA) in 1971. Grandfathered facilities were not required to comply with (i.e., grandfathered from) the then new requirement to obtain permits for construction or modifications of facilities that emit air contaminants. If a grandfathered facility has not been modified since 1971, then it has continued to be authorized to operate without a permit.

The 1997 Texas Legislature passed a bill requiring the state's environmental agency to develop a voluntary program. This program was enacted in 1999, and offered companies the choice to apply for a permit. Because there was little incentive to apply for the permit, few did.

The 2001 Texas Legislature finally required grandfathered facilities to obtain a permit in order to continue operating. Permits for grandfathered facilities are relatively weak – a company applying for a permit to build or expand a similar facility at roughly the same time would be expected to install much better pollution control technology.

Regardless of its deficiencies, once companies finally receive either a voluntary or mandatory permit for grandfathered facilities, pollution levels should noticeably decrease in the Houston area. For further information, visit (www.tnrcc.state.tx.us/permitting/airperm/grandfathered/).

R. Diesel emissions are to be reduced by federal and state programs.

Federal transportation funding includes a category of funding known as Congestion Mitigation and Air Quality funds. In the Houston region, these funds are administered through the Houston-Galveston Area Council. In addition to specific grants of federal transportation funds for purchase of low-emission buses, HGAC administers several programs intended to reduce transportation emissions, such as funding vanpools. HGAC may also make other grants for other on-road emission reductions through the Clean Cities/Clean Vehicles program (www.houston-cleancities.org/).

The US Environmental Protection Agency is phasing in new engine manufacture regulations and other measures to reduce emissions from on-road and off-road diesel engines. These measures begin to take effect in 2004, with the most significant reductions beginning in 2007.

Texas offers financial incentives and other programs to reduce pollution from diesel engines and other similar sources through the Texas Emission Reduction Program (TERP). Information on TERP is available at www.tnrcc.state.tx.us/oprd/sips/terp.html.

S. Texas tightened up controls, but targeted only four chemicals, and is reconsidering many of those rules.

On December 13, 2002, the Texas Commission on Environmental Quality (TCEQ) adopted revisions to the State Implementation Plan (SIP), Texas' plan for complying with the Clean Air Act. All of the revisions affected the Houston region, and some were effective statewide as well. The TCEQ adopted new rules that address the impact of highly-reactive volatile organic compounds (HRVOCs) from industrial sources on rapid ozone formation in the Houston/Galveston area.

HRVOCs are defined by the TCEQ as ethylene, propylene, butadiene, and butanes. These chemicals represent 50-70% of industrial-area VOC emissions, when measured by the capacity to cause ozone formation (reactivity). (There are rules affecting the other VOCs, but they are not as specific.)

The HRVOC rules include two methods for ensuring reductions in these emissions. First, the TCEQ expanded regulation of monitoring and operating requirements for cooling towers, flares, fugitives (leaks) and process vents. Second, the TCEQ established a “cap” and required sources covered by the cap to reduce HRVOC emissions by about two-thirds. Because some sources are not covered by the cap, and because all emissions during startup, shutdown, maintenance and upset conditions are exempted from the cap, the total emissions of HRVOCs are not reduced by anywhere near two-thirds. The TCEQ has not calculated how effective its regulations and “cap” will be at reducing emissions of HRVOCs, although its scientific studies assume that emissions will be reduced by the amount established under the “cap” (even though some emissions are exempted from the cap).

T. In 2002, Texas rolled back forthcoming standards affecting industry.

On December 13, 2002, the Texas Commission on Environmental Quality (TCEQ) adopted revisions to the State Implementation Plan (SIP), Texas' plan for complying with the Clean Air Act. All of the revisions affected the Houston region, and some were effective statewide as well. The TCEQ increased the amount of nitrogen oxide (NOx) emissions allowed from point sources in the Houston region by about two-thirds, from 87 tons per day to 143 tons per day.

Table T-1: Industrial NOx Emissions in the Houston Region

	Tons per day	Reduction
Actual (Estimated) 2000 Emissions	472	
So-called “90%” reduction: allowable 2007 emissions	87	82%
So-called “80%” reduction: allowable 2007 emissions	143	70%

Source: Texas Commission on Environmental Quality, emission inventory and December 13, 2002 revision to State Implementation Plan.