Southern Delaware County Air Monitoring Project

Second Interim Report

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Commonwealth of Pennsylvania
Department of Environmental Protection
Bureau of Air Quality

Tom Ridge, Governor
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www.dep.state.pa.us

Summary

In 1994, the United States Environmental Protection Agency (EPA), in cooperation with the Pennsylvania Department of Environmental Protection (DEP), began an environmental risk study for the City of Chester. Early in 1995, DEP, in cooperation with EPA, began sampling for volatile organic air pollutants in Chester and Marcus Hook. The study was expanded in 1997 by including a sampling site in Swarthmore. The goal of this study is to learn more about the air quality in Southern Delaware County and to determine what pollutants are present. This second interim report is a summary of what has been learned so far. It briefly describes the air sampling and analysis methods, which were described in more detail in the December 1996 first interim report. The study is continuing, so there will be future reports when more information has been collected.

DEP is collecting air samples at three locations: Front Street and Highland Avenue in Chester, Eighth and Market Streets in Marcus Hook, and 500 College Avenue in Swarthmore. The Maryland Department of the Environment, Air Management Administration (MDE), analyzes the samples under a cooperative agreement with EPA. DEP also has an air monitoring station at Front and Norris Streets in Chester where other air pollutants are measured and where air samples are collected for particulates and metals.

The Chester and Marcus Hook sites were chosen to gain information about concentrations of toxic pollutants in Southern Delaware County. Both sites are close to several industrial facilities and near roads with high traffic volumes. DEP started collecting air samples in Chester on January 10, 1995, and in Marcus Hook on April 2, 1995. On January 22, 1997, DEP began air sampling in Swarthmore to have a non-industrial site for comparison.

All of the air samples were analyzed for a selected list of chemical pollutants. The second part of this report gives an estimate of the excess lifetime cancer risk due to inhalation of these pollutants. The data analysis and conclusions are solely those of DEP and may not reflect the views or opinions of EPA or MDE. On a national average, roughly 4,000 out of 10,000 people will develop cancer in their lifetimes. (One out of 10,000 is 0.01 percent.) If the people who live in Chester were exposed continuously for 70 years to the average air pollutant concentrations measured in 1997, then about 1.3 more people in every 10,000 living in Chester might develop some kind of cancer from these pollutants.

In Marcus Hook, the situation is very similar. If people who live in Marcus Hook were exposed continuously for 70 years to the average pollutant concentration measured in 1997, then about 1.4 more people in every 10,000 might develop some kind of cancer from the pollutants. For Swarthmore, 1.1 more people in every 10,000 might develop cancer over a lifetime of 70 years.

These risks are similar to other urban areas. Please note these are the sums of the individual risks for all of the pollutants studied that have cancer risk factors, and include toxic metals that were not in the 1996 report. Risk estimates calculated with the average concentrations measured during 1995 yielded somewhat higher cancer risks. The inhalation cancer risks,

assuming people were exposed continuously to the average concentrations measured in 1995, were 1.7 and 1.8 in every 10,000 people for Chester and Marcus Hook, respectively.

DEP also has compared the data collected in Southern Delaware County to data from a similar monitoring program in and around Baltimore, Maryland. The overall excess lifetime cancer risk associated with these pollutants is slightly higher in the Baltimore area than in Chester, Marcus Hook or Swarthmore. The risk analyses are summarized in Tables 2.1 through 2.6.

Of the pollutants measured, the five that pose the greatest risk to human health in Chester and Marcus Hook are 1,3-butadiene, 1,2-dibromoethane, benzene, carbon tetrachloride and vinyl chloride. Some sources for these types of compounds are gasoline, motor vehicles, petroleum distillates, consumer and industrial chemicals containing solvents, and naturally-occurring emissions from vegetation and decomposition.

On February 27, 1997, DEP began a study of particulate matter and toxic metals at the three sites. Air samples of particulate matter less than 10 microns in size (PM-10) and total suspended particulate (TSP) are collected on quartz fiber filters, which are then analyzed for toxic metals. Table 2.4 summarizes the average air concentrations of metals and particulates, and presents an estimate of the excess lifetime cancer risks from inhalation of the metals. Estimated inhalation cancer risks from metals, based on the exposure conditions given above, were 0.076 for every 10,000 in Chester, 0.066 for every 10,000 in Marcus Hook and 0.053 for every 10,000 in Swarthmore.

This report first describes the sampling and analysis procedures, followed by a description of the toxicity assessments and inhalation risk characterizations. The appendix includes an explanation of scientific notation, which is used for some of the numbers in the tables, the equations and factors used in the risk analysis, and definitions of some of the technical terms. The raw pollutant concentration data that were used to estimate the risks can be obtained from the DEP Southeast Regional Office at (610) 832-6242, or by visiting the DEP website at www.dep.state.pa.us (Choose Subjects/Air Quality/Ambient Air Monitoring).

Air Monitoring and Analysis

Overview of Project Status through December 1997

In 1995, DEP, working with EPA Region III, began measuring the concentrations of certain pollutants in the ambient air to learn more about the air quality in Southern Delaware County. An interim report released on December 17, 1996, covered the initial air sampling results and presented a preliminary assessment of the risk. This report summarizes data for air samples collected in Chester and Marcus Hook through the end of 1997. It also presents data for a new sampling site in Swarthmore, Pennsylvania. This site was added to the study to provide a comparison to Chester and Marcus Hook because it is also in Southern Delaware County (the same air basin), but not as close to large industrial sources.

The sampling sites in Chester and Marcus Hook were chosen because they are close to several industrial facilities and near roads with high traffic volumes. DEP started collecting air samples in Chester on January 10, 1995, and in Marcus Hook on April 2, 1995. Sampling started at Swarthmore on January 22, 1997.

Air samples are analyzed for volatile organic compounds and hydrocarbons by the Maryland Department of the Environment, Air Management Administration's (MDE's) laboratory. In this report, as in the first interim report released in December 1996, results are given for the volatile organic compounds listed in Table 1.1 (Organics). The chemicals listed in Table 1.1 are targeted primarily because they are toxic and their presence in the ambient air contributes to the inhalation risk. Additionally, this report summarizes data for the volatile hydrocarbons listed in Table 1.2 (Hydrocarbons). Since the last report was released, DEP has begun sampling for particulates and toxic metals. Therefore, this report includes data on organics, hydrocarbons, toxic metals, total suspended particulate matter (TSP) and particulate matter less than 10 microns in size (PM-10). The study is still continuing, so additional data will be made available to the public as more samples are collected and analyzed.

Of the pollutants measured, the five that pose the greatest risk to human health in Chester and Marcus Hook are 1,3-butadiene, 1,2-dibromoethane, benzene, carbon tetrachloride and vinyl chloride. Vinyl chloride is used to make plastics and is a decomposition product of some other chlorinated organic compounds. Benzene and 1,3-butadiene are common industrial chemicals present in small amounts in gasoline and motor vehicle emissions. They are also emitted from agricultural burning and forest fires. 1,2-dibromoethane is used as a fumigant and in anti-knock gasoline. Carbon tetrachloride is used as a solvent and grain fumigant. It was formerly used as a refrigerant and in some fire extinguishers.

Every air sample is tested to see if it contains any of the compounds listed in Tables 1.1 and 1.2. The concentrations are used to estimate the excess lifetime cancer risk resulting from inhalation exposure to these pollutants. The average concentrations reported here are different than in the December 1996 interim report. In that report, when a chemical was not detected, a concentration of 0.0 parts per billion was used for calculating the average. The averages in this report were calculated using one-half of the laboratory's minimum detection

limit (MDL) when a chemical was not detected. This is a more conservative assumption and gives slightly higher average concentrations.

During 1995 and 1996, DEP collected canister samples at Chester and Marcus Hook on two days out of three. Since the Swarthmore site was added, air samples have been collected two days in a row out of every six days so as not to increase the laboratory workload. A six-day schedule is used so sampling falls on different days of the week over the course of the year.

The same six-day schedule is used to sample for total suspended particulate and PM-10 on quartz fiber filters. The DEP laboratory analyzes these filters for the following metals: arsenic, beryllium, cadmium, chromium, hexavalent chromium (Cr^{+VI}), lead, nickel and zinc. Hexavalent chromium is more toxic than other forms of chromium and is known to cause cancer.

The initial plan for this study was to sample for one year at Chester and Marcus Hook. After reviewing the data from the first nine months of sampling, DEP and EPA decided to continue sampling for several reasons:

- to collect samples at a comparison site in Swarthmore, Pennsylvania;
- to determine whether there were any trends or changes in pollutant concentrations;
- to better assess the long-term exposures; and
- to measure particulate matter and toxic metals.

Study Participants

The sampling and analysis program is part of a study undertaken by DEP, in cooperation with EPA. The MDE Air Management Administration's laboratory analyzes the canister samples under a cooperative agreement with EPA Region III. The DEP Bureau of Laboratories analyzes the quartz filter samples for metals and particulates. The data analyses and conclusions in this report are solely those of DEP and may not reflect the views or opinions of EPA or MDE.

Canister Sampling for Volatile Organic Compounds

The first interim report described the canister sampling method in detail, so only a brief description of the sampling and analytical methods is given here. Air samples are collected in SUMMA® canisters, which are stainless steel canisters specially treated to create an inert inner surface. The canisters are cleaned and evacuated in the laboratory, then shipped to the sampling site where they are filled with air at a constant rate over the sampling period. The filled canisters are then shipped back to the laboratory for analysis.

Canister samples are being collected at three sites: Front Street and Highland Avenue in Chester, Eighth and Market Streets in Marcus Hook, and 500 College Avenue in Swarthmore. These locations are marked in Figures 1.1 and 1.2, and the latitude and longitude coordinates

appear in the appendix. Canister samples are collected over a 23-hour, 55-minute period from midnight to 11:55 PM.

Each canister is analyzed by two different methods. First, gas chromatography/mass spectrometry (GC/MS) using selected ion monitoring (SIM) is used to analyze for the compounds specified in EPA Method TO-14[1]. This method is sensitive and accurate for a selected list of non-polar hydrocarbons and halogenated hydrocarbons; however, only organic compounds on the target compound list can be identified. The target list of approximately 40 compounds includes the most common chlorinated and non-polar industrial solvents. With selected ion monitoring, the GC/MS is programmed only to look for the "fingerprints" that identify target compounds. Therefore, other organic compounds that might be present are not detected. Table 1.1 (Organics) lists the target compounds for the GC/MS SIM analysis. The results for these compounds are reported by the laboratory in parts per billion volume (ppbv). In order to calculate the risk, the average concentrations are converted to micrograms per cubic meter of air.

The second analytical method is gas chromatography with flame ionization detection (GC/FID). The system is calibrated for the hydrocarbon compounds listed in Table 1.2 (Hydrocarbons). EPA selected these compounds for the photochemical assessment monitoring program. The laboratory reports the pollutant concentrations from the GC/FID analyses in parts per billion carbon (ppbC), which is equal to ppbv multiplied by the number of carbon atoms in the compound. Chemists use these units because the FID response for hydrocarbons is approximately proportional to the number of carbon atoms. These units are also used in AIRS-AQS, EPA's national database of air quality data. The concentrations of these chemicals may help to show the relative influence of mobile sources (motor vehicles) and stationary sources when further data analysis is conducted.

Particulate Sampling

Particulate samples are collected at the same locations as canister samples in Swarthmore and Marcus Hook. Adequate electrical power was not available to operate particulate samplers at the Chester canister sampling site, so the samplers were located at the Commonwealth of Pennsylvania Air Monitoring Station (COPAMS) at Front and Norris Streets in Chester (see Figures 1.1 and 1.2).

At each site, a GMWL-2000 total suspended particulate sampler and a GMW-321B PM-10 sampler are placed approximately 10 feet apart. The samplers are operated and audited following the procedures in the DEP Bureau of Air Quality's Quality Assurance Manual, with the exception that the sampling period is 48 hours rather than 24 hours. This longer sampling period improves the minimum detection limits by a factor of two.

All particulate filters are analyzed for the following metals: arsenic, beryllium, cadmium, total chromium, chromium^{+VI}, lead, nickel and zinc. Arsenic, beryllium, cadmium, total chromium,

[1] Winberry, William T. , Norma T. Murphy and R. M. Riggin, Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, EPA/600/4-89/017, 1988.

lead, nickel and zinc are measured by inductively coupled plasma mass spectrometry (ICP-MS). Chromium^{+VI} is measured by ion chromatography. Initially, glass fiber filters were used to collect TSP samples for metals and quartz fiber filters were used for PM-10. Blank levels of chromium^{+VI} were too high on the glass fiber filters, so after July 1997 the TSP samplers were switched to also use quartz fiber filters. These had acceptable blank levels for all of the metals. (Blank level refers to the traces of pollutants present in the materials used for sample collection and analysis . The method is invalid if the blank levels are too high or variable compared to the required detection limit.)

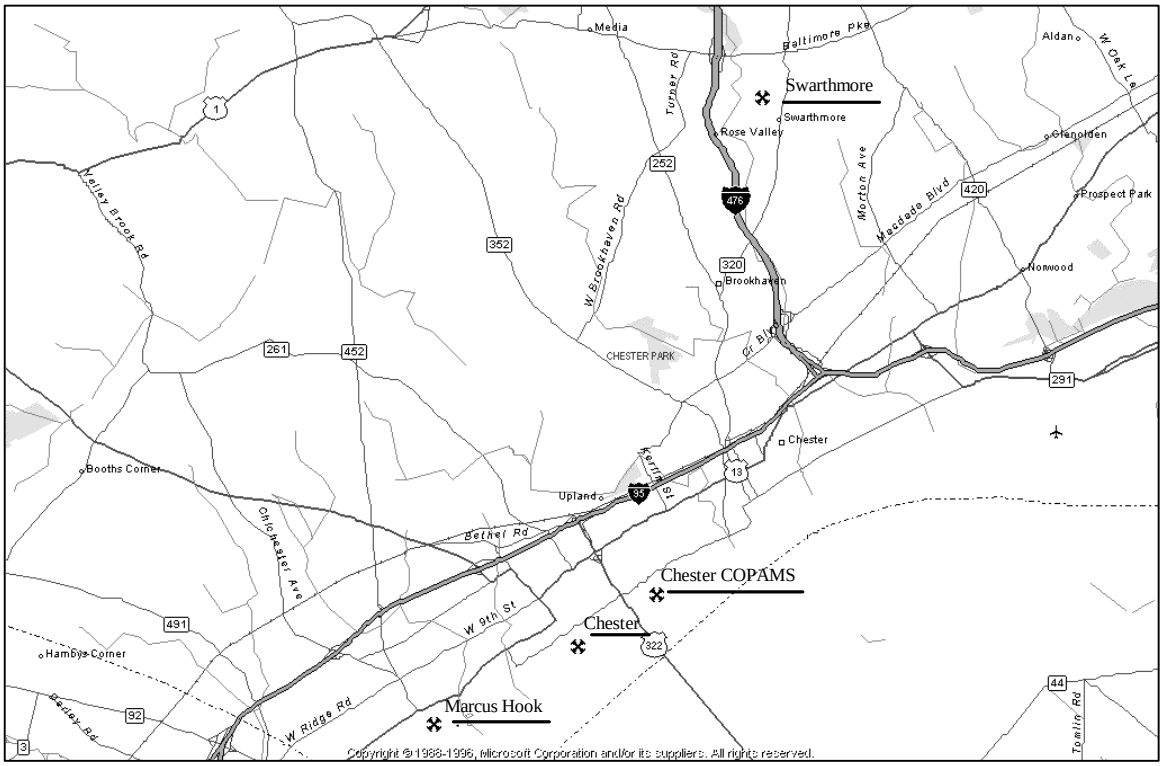


Figure 1.1 Air Sampling Site Locations

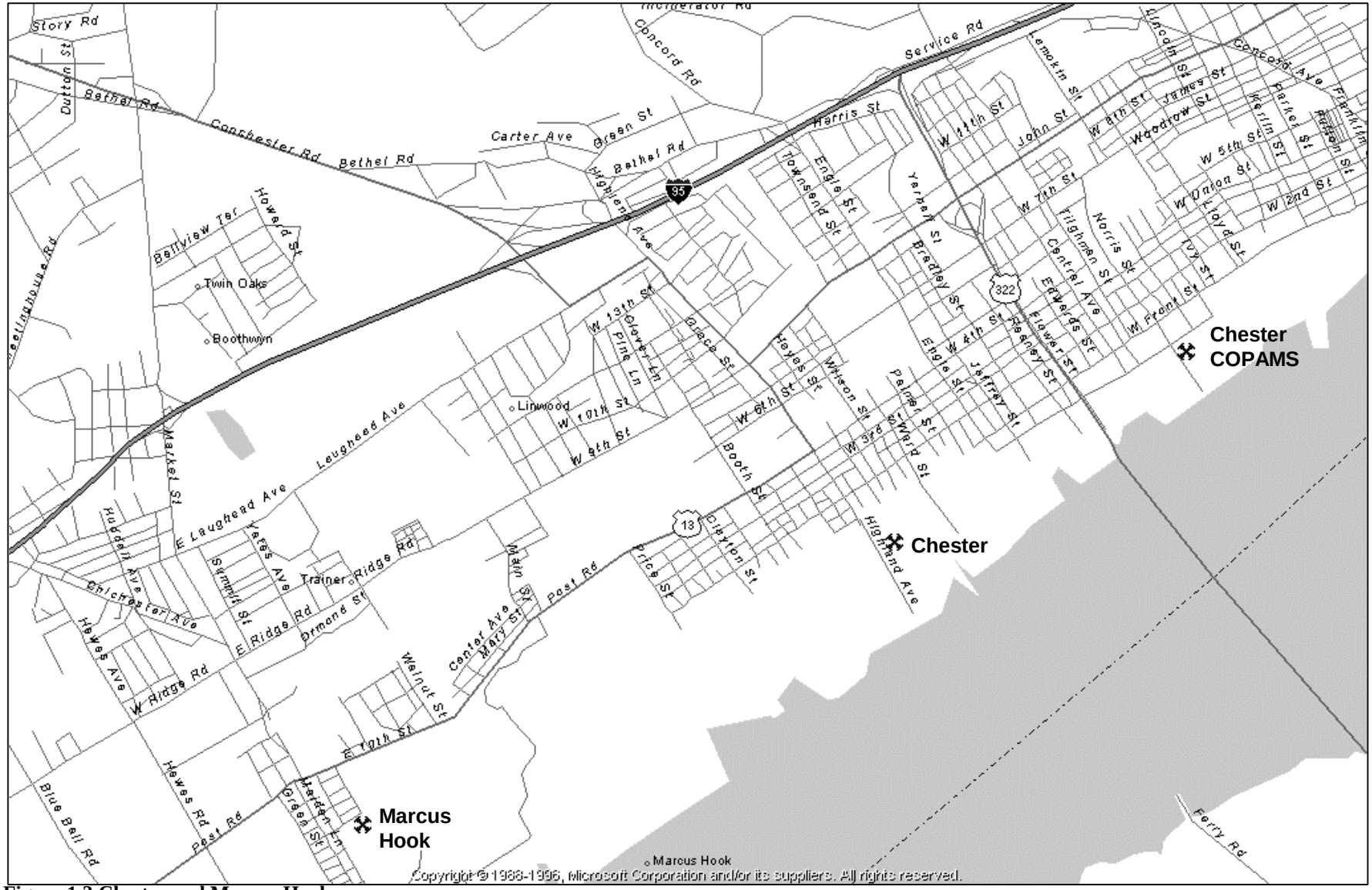


Figure 1.2 Chester and Marcus Hook

Table 1.1 Organic Compounds

COMPOUND	CAS	MDL	COMPOUND	CAS	MDL
Dichlorodifluoromethane	75-71-8	0.006	trans-1,3-Dichloropropene*	10061-02-6	0.020
Chloromethane	74-87-3	0.030	1,1,2-Trichloroethane	79-00-5	0.020
1,2-Dichloro-1,1,2,2-tetrafluoroethane	76-14-2	0.006	Toluene	127-18-4	0.009
Chloroethene (Vinyl Chloride)	75-01-4	0.020	1,2-Dibromoethane	106-93-4	0.010
1,3-Butadiene	106-99-0	0.060	Tetrachloroethene	127-18-4	0.020
Bromomethane	74-83-9	0.010	Chlorobenzene	108-90-7	0.010
Chloroethane	75-00-3	0.030	Ethylbenzene	100-41-4	0.008
Trichlorofluoromethane	75-69-4	0.009	m & p-Xylene	1330-20-7	0.010
1,1-Dichloroethene	75-35-4	0.009	Styrene	100-42-5	0.020
Methylene chloride	75-09-2	0.010	1,1,2,2-Tetrachloroethane	79-34-5	0.009
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	0.010	o-Xylene	95-47-6	0.010
1,1-Dichloroethane	75-34-3	0.010	1-Ethyl-4-methyl benzene	622-96-8	0.007
cis 1,2-Dichloroethene	156-59-2	0.020	1,3,5-Trimethylbenzene	108-67-8	0.010
Chloroform	67-66-3	0.007	1,2,4-Trimethylbenzene	95-63-6	0.008
1,2-Dichloroethane	107-06-2	0.020	Chloromethylbenzene	100-44-7	0.010
1,1,1-Trichloroethane	71-55-6	0.010	1,3-Dichlorobenzene	95-50-1	0.010
Benzene	71-43-2	0.009	1,4-Dichlorobenzene	106-46-7	0.009
Carbon tetrachloride	56-23-5	0.010	1,2-Dichlorobenzene	541-83-1	0.008
1,2-Dichloropropane	78-87-5	0.020	1,2,4-Trichlorobenzene	95-63-6	0.010
Trichloroethene	79-01-6	0.020	Hexachloro-1,3-butadiene	87-68-3	0.030
cis-1,3-Dichloropropene*	10061-01-5	0.020			

CAS - Chemical Abstract Service Number that uniquely identifies a chemical compound under the Toxic Substances Control Act.

MDL - The analytical laboratory's minimum detection limit in parts per billion by volume.

* cis-1,3-Dichloropropene and trans-1,3-Dichloropropene are reported separately, but are added together for purposes of risk analysis. The CAS number for the mixture is 542-75-6.

Table 1.2 Hydrocarbon Compounds

Compound	CAS	Compound	CAS
Ethene	74-85-1	2,3-Dimethylpentane	565-59-3
Ethyne (Acetylene)	74-86-2	3-Methylhexane	589-34-4
Ethane	74-84-0	2,2,4-Trimethylpentane	540-84-1
Propene	115-07-1	n-Heptane	142-82-5
n-Propane	74-98-6	Methylcyclohexane	108-87-2
2-Methylpropane	75-28-5	2,3,4-Trimethylpentane	565-75-3
1-Butene	106-98-9	Toluene	108-88-3
n-Butane	106-97-8	2-Methylheptane	592-27-8
trans-2-Butene	624-64-6	3-Methylheptane	589-81-1
cis-2-Butene	590-18-1	n-Octane	111-65-9
2-Methylbutane	78-78-4	Ethylbenzene	100-41-4
1-Pentene	109-67-1	m&p-Xylene	108-38-3
n-Pentane	109-66-0	Styrene	100-42-5
2-Methyl-1,3-Butadiene (isoprene)	78-79-5	o-Xylene	95-47-6
trans-2-Pentene	646-04-8	n-Nonane	111-84-2
cis-2-Pentene	627-20-3	Isopropylbenzene	98-82-8
2,2-Dimethylbutane	75-83-2	n-Propylbenzene	103-65-1
Cyclopentane	287-92-3	1-Ethyl-3-methylbenzene	620-14-4
2,3-Dimethylbutane	79-29-8	1-Ethyl-4-methylbenzene	622-96-8
2-Methylpentane	107-83-5	1,3,5-Trimethylbenzene	108-67-8
3-Methylpentane	96-14-0	1-Ethyl-2-methylbenzene	611-14-3
2-Methyl-1-pentene	763-29-1	1,2,4-Trimethylbenzene	95-63-6
n-Hexane	110-54-3	n-Decane	124-18-5
Methylcyclopentane	96-37-7	1,2,3-Trimethylbenzene	526-73-8
2,4-Dimethylpentane	108-08-7	1,3-Diethylbenzene	141-93-5
Benzene	71-43-2	1,4-Diethylbenzene	105-05-5
Cyclohexane	110-82-7	n-Undecane	1120-21-4
2-Methylhexane	591-76-4		

CAS - Chemical Abstract Service Number that uniquely identifies a chemical compound under the Toxic Substances Control Act.

Discussion of Results

Organic Compounds

At the start of the study, the MDE laboratory tested the canister samplers for background contamination. They were leak-checked and cleaned, then purged with humidified, ultra-pure air until the canisters had less than 20 ppbC total contaminants. Although the samplers passed the quality control check for total contaminants, it was later found that two of the samplers at Chester had background contamination of up to a few ppbv for three of the target compounds: styrene, ethylbenzene and 1,3-butadiene. The Chester samplers were replaced with an AVOCS multi-canister sampler in April 1995 to eliminate the contamination problem. In June 1997, the sampler at Marcus Hook was repaired; however, it was later found that the repair parts were contaminated with several target compounds: 1-ethyl-4-methylbenzene, trimethylbenzene isomers, nonane and decane. Data for these compounds were voided between June 21, 1997, and September 14, 1997. Results for the other compounds were not affected. Data for March 1997 at the Swarthmore site were voided because the canisters were not filling to the correct final pressure.

The annual average concentrations are the arithmetic averages of all valid 24-hour samples in the calendar year. When the compound was not detected, one-half of the minimum detection limit was used to calculate the average. In a few cases, the laboratory reported values below their usual MDL, and these values were used to calculate the average. Table 1.1 gives the minimum detection limits for the GC/MS SIM analysis. In the December 1996 interim report, the averages were calculated using 0.00 ppbv for non-detects. For this second interim report, DEP chose to use the more conservative assumption of one-half the minimum detection limit in the cases of non-detects. The average concentrations were calculated both ways, and the differences in the overall calculated risks were very small.

For purposes of calculating the excess lifetime cancer risks, DEP used the arithmetic averages as an approximation to the annual average air concentrations. Sometimes scientists use other statistical values to estimate the risk, such as the geometric mean or 95 percent upper confidence limit. The raw data are available in Excel 5.0 spreadsheet format for anyone wishing to conduct their own risk assessment.

Hydrocarbon Compounds

This report includes data for the volatile hydrocarbons listed in Table 1.2 (Hydrocarbons). Table 1.3 summarizes the 1997 annual average hydrocarbon concentrations at the three monitoring sites.

Several aromatic compounds are on both the organic compound list and the hydrocarbon list. Table 1.4 is a comparison of the 1997 annual average concentrations as determined by the two analytical methods. The overall agreement was excellent, except for styrene, which was near or below the MDL in many samples. This overall agreement provides confidence that the individual analytical methods are accurate.

Table 1.3 1997 Hydrocarbon Concentrations in ppbC

	Chester				Marcus Hook				Swarthmore			
COMPOUND	**Min**	**Max**	**Mean**	**Std Dev**	**Min**	**Max**	**Mean**	**Std Dev**	**Min**	**Max**	**Mean**	**Std Dev**
Ethylene	0.29	25.04	6.16	4.72	1.75	112.94	17.74	20.58	0.74	19.71	4.03	3.02
Acetylene	0.89	15.86	3.97	2.96	0.33	14.14	3.90	2.48	0.86	10.51	3.02	1.96
Ethane	3.42	26.11	10.09	5.11	3.69	142.08	14.80	15.59	2.76	20.38	7.32	3.54
Propene	0.22	168.46	7.93	16.68	1.08	833.30	43.45	93.02	0.44	19.85	3.60	3.74
Propane	2.61	167.07	19.74	20.54	5.05	940.50	60.00	127.88	2.32	54.35	10.67	7.96
Isobutane	0.63	344.01	14.29	35.27	1.51	442.30	22.80	49.31	0.51	18.30	3.62	3.28
1-Butene	0.33	32.78	2.55	3.23	0.52	16.09	3.15	2.32	0.48	6.06	1.50	1.03
Butane	1.63	307.56	23.13	35.82	3.94	813.30	40.71	82.57	1.26	37.96	7.70	6.96
t-2-Butene	0.09	17.62	0.92	1.75	0.00	10.09	1.59	1.45	0.00	2.15	0.30	0.31
c-2-Butene	0.09	13.07	1.22	2.02	0.23	11.86	1.58	1.70	0.00	6.38	0.55	0.99
Isopentane	0.52	76.88	15.12	13.07	3.88	249.11	24.77	27.06	1.27	19.74	6.24	3.78
1-Pentene	0.00	12.14	1.57	2.62	0.00	11.10	1.30	1.90	0.10	6.01	0.68	0.95
Pentane	0.45	71.96	8.24	9.03	1.08	283.11	14.48	26.77	0.89	21.04	3.51	2.83
Isoprene	0.00	4.46	0.87	0.94	0.00	4.57	0.92	0.91	0.00	10.70	1.61	2.04
t-2-Pentene	0.00	5.14	0.84	0.70	0.00	5.74	1.31	1.00	0.00	1.32	0.31	0.24
c-2-Pentene	0.00	3.11	0.64	0.47	0.00	9.35	1.23	1.44	0.00	0.75	0.22	0.15
2,2-Dimethylbutane	0.00	2.33	0.74	0.42	0.23	4.70	1.13	0.78	0.00	1.51	0.43	0.24
Cyclopentane	0.14	8.26	1.03	1.09	0.22	19.01	1.66	2.01	0.19	1.38	0.50	0.25
2,3-Dimethylbutane	0.14	5.84	1.44	0.91	0.00	8.73	2.50	1.48	0.26	2.34	0.80	0.42
2-Methylpentane	0.17	18.12	4.05	3.02	1.31	59.82	8.20	7.78	0.42	6.56	2.01	1.26
3-Methylpentane	0.71	22.07	4.56	4.13	1.22	34.28	6.42	5.30	0.37	7.67	1.65	1.24
2-Methyl-1-Pentene	0.00	5.56	0.91	0.95	0.00	1.82	0.61	0.41	0.00	3.53	1.21	0.80
Hexane	0.10	21.69	3.31	2.98	0.95	75.29	6.56	7.99	0.10	6.06	1.93	1.11
Methylcyclopentane	0.25	18.39	3.16	3.13	0.50	32.91	4.24	4.17	0.20	3.05	0.96	0.60
2,4-Dimethylpentane	0.00	5.48	0.79	0.62	0.20	4.72	1.27	0.75	0.12	1.34	0.39	0.24
Benzene	0.60	47.13	5.51	7.18	1.39	30.77	5.24	3.87	0.84	7.84	2.35	1.21
Cyclohexane	0.29	18.05	2.34	2.52	0.16	28.54	3.47	3.77	0.11	2.46	0.75	0.44
2-Methylhexane	0.17	30.42	5.13	5.45	0.50	14.50	3.18	2.53	0.22	3.79	1.04	0.69
2,3-Dimethylpentane	0.15	14.09	2.51	2.39	0.39	6.41	1.78	1.20	0.22	2.28	0.68	0.42
3-Methylhexane	0.18	63.47	8.81	10.55	0.51	29.18	4.29	4.07	0.31	4.96	1.15	0.84
2,2,4-Trimethylpentane	0.22	14.81	2.62	2.33	0.96	19.64	4.29	3.30	0.43	4.81	1.53	0.93
Heptane	0.16	84.00	11.14	14.09	0.53	33.87	4.68	4.99	0.30	5.42	1.13	0.90
Methylcyclohexane	0.00	189.18	4.81	17.68	0.34	27.20	4.26	4.29	0.17	4.22	0.73	0.60
2,3,4-Trimethylpentane	0.00	10.59	1.01	1.17	0.33	11.02	1.94	1.81	0.14	2.43	0.54	0.40
Toluene	0.71	31.42	9.83	6.50	3.69	64.32	15.73	10.84	1.88	22.77	5.76	3.63
2-Methylheptane	0.00	3.69	0.72	0.57	0.16	6.90	1.29	0.93	0.00	1.81	0.36	0.27
3-Methylheptane	0.00	3.58	0.91	0.50	0.27	6.29	1.25	0.82	0.00	1.90	0.44	0.28
Octane	0.17	8.97	1.40	1.21	0.31	14.47	2.31	2.00	0.20	3.25	0.67	0.45

Table 1.3 Continued

	Chester				Marcus Hook				Swarthmore			
COMPOUND	**Min**	**Max**	**Mean**	**Std Dev**	**Min**	**Max**	**Mean**	**Std Dev**	**Min**	**Max**	**Mean**	**Std Dev**
Ethylbenzene	0.34	37.40	3.10	4.09	0.28	7.28	2.35	1.18	0.26	2.87	0.90	0.51
M & P-Xylene	0.81	121.60	9.81	13.32	0.18	23.66	7.53	4.05	0.69	8.58	2.65	1.63
Styrene	0.17	3.67	0.78	0.57	0.15	6.58	0.88	0.97	0.00	1.20	0.38	0.27
o-Xylene	0.74	32.24	3.45	3.53	0.46	7.53	2.97	1.41	0.38	4.08	1.24	0.75
Nonane	0.14	14.02	1.63	1.76	0.13	4.82	1.32	0.89	0.13	1.76	0.52	0.34
Isopropylbenzene	0.11	1.98	0.60	0.43	0.10	1.82	0.51	0.38	0.00	42.60	1.58	6.65
Propylbenzene	0.15	2.90	0.72	0.39	0.09	2.13	0.57	0.38	0.00	2.18	0.39	0.32
1-Ethyl-3-Methylbenzene	0.00	4.55	1.65	0.92	0.00	5.24	1.51	0.91	0.00	3.00	1.08	0.60
1-Ethyl-4-Methylbenzene	0.00	5.58	1.14	0.70	0.27	3.15	0.95	0.51	0.00	1.75	0.60	0.35
1,3,5-Trimethylbenzene	0.12	3.05	0.97	0.56	0.20	3.65	0.88	0.52	0.11	1.52	0.45	0.30
1-Ethyl-2-Methylbenzene	0.23	5.66	1.43	0.84	0.20	2.96	0.88	0.50	0.14	2.21	0.68	0.40
1,2,4-Trimethylbenzene	0.50	11.09	2.68	1.58	0.56	8.11	2.43	1.40	0.49	4.77	1.48	0.89
Decane	0.15	16.09	2.40	2.04	0.21	16.22	1.77	1.99	0.25	3.43	1.04	0.62
1,2,3-Trimethylbenzene	0.12	88.98	22.23	25.83	0.10	7.70	1.80	1.45	0.15	4.79	1.18	0.87
m-Diethylbenzene	0.00	2.54	0.69	0.35	0.09	3.09	0.49	0.36	0.00	1.23	0.40	0.22
p-Diethylbenzene	0.00	1.30	0.44	0.23	0.13	2.20	0.42	0.30	0.00	0.84	0.26	0.16
Undecane	0.10	5.07	1.25	0.84	0.10	58.93	1.64	6.09	0.00	2.29	0.79	0.47
TNMOC	72.08	1845.8	401.83	253.52	95.62	3388.4	484.40	410.86	53.17	376.65	149.71	69.78
PAMSHC	38.89	1216.4	248.9	163.67	69.17	3249.0	357.58	383.76	29.10	289.15	97.47	55.39

Analysis by GC/FID.
TNMOC=Total non-methane organic compounds.
PAMSHC=Sum of PAMS target compounds.

Table 1.4 1997 Annual Average Concentrations by GC/FID Compared to GC/MS SIM

	Chester			Marcus Hook			Swarthmore		
	FID ppbv	SIM ppbv	Percent Difference	FID ppbv	SIM ppbv	Percent Difference	FID ppbv	SIM ppbv	Percent Difference
Benzene	0.92	0.86	6.6	0.87	0.83	5.0	0.39	0.37	6.5
Toluene	1.40	1.38	1.7	2.25	2.26	-0.6	0.82	0.78	5.2
m&p-Xylene	1.23	1.27	-3.5	0.94	1.05	-10.9	0.33	0.34	-2.9
Ethylbenzene	0.39	0.40	-2.2	0.29	0.30	-2.8	0.11	0.11	-0.4
Styrene	0.10	0.05	56.7	0.11	0.07	39.5	0.05	0.03	42.0
o-Xylene	0.43	0.40	7.0	0.37	0.35	5.0	0.16	0.13	16.8

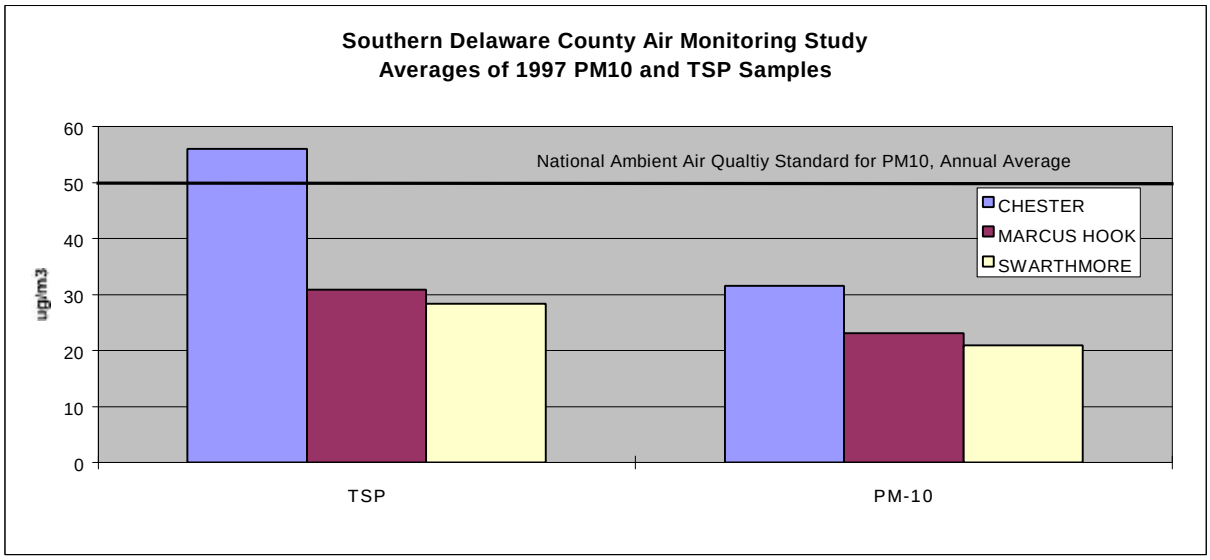
Particulates and Metals Sampling

Sampling for particulates and metals started on March 5, 1997, so the amount of data used to estimate the 1997 annual average covers less than a full year. As noted above, samples for metals were initially collected on glass fiber filters. The laboratory found that the background levels of hexavalent chromium were too high and variable to achieve the desired detection limits. The TSP samplers were switched to quartz fiber filters on August 2, 1997, and all hexavalent chromium data for samples collected on glass fiber filters were voided. This compound has not been detected in samples at any of the three sites.

The arithmetic means of all valid samples were used as estimates of the inhalation exposure concentration of each pollutant for the risk characterization. One-half of the minimum detection limits were used for non-detects. Because some of the particles collected by the TSP samplers are too large to be inhaled, the estimates of the inhalation exposures may be conservative.

The particulate sampling site in Chester is located on an industrial property where there was construction and earth-moving near the samplers during part of the year. Also, the Chester sampler's inlet is about two meters above ground-level, while the Marcus Hook and Swarthmore sites are both on the rooftops of buildings with the inlets between 10 and 15 meters above ground-level. This may have somewhat biased the results against Chester. Figure 1.3 shows the average TSP and PM-10 concentrations at the three sites.

Figure 1.3 Comparison of the Average TSP and PM-10 Concentrations



Toxicity Assessment and Inhalation Risk Characterization

Overview of Risk Factors and Reference Doses

The excess lifetime cancer risk for each of the chemicals was calculated using unit risk factors (URFs), and the risk for non-cancer health effects was calculated using reference air concentrations (RfCs). The URF is a measure of the probability of developing cancer from exposure over a lifetime to a specified concentration of a given chemical. The RfC is the concentration below which no (non-cancer) adverse health affects are expected to occur over a lifetime of continuous exposure. The EPA Region III Superfund Technical Support Section's risk-based concentration (RBC) table was the primary source for the risk factors. In some cases, there were no inhalation risk data for a chemical in the RBC table and other sources, such as the Boilers and Industrial Furnaces (BIF) Regulation, had to be referenced. Appendix Table A.1 gives all of the URFs and RfCs, and summarizes their sources. EPA has revised some of the risk factors since the first interim report was released, and these changes are also listed in the appendix. Of the organic chemicals on the GC/MS target list, a total of 36 had data for either the inhalation reference dose or inhalation cancer potency slope (from which the RfC and URF are derived). Six of the metals had data for either the inhalation reference dose or inhalation cancer potency slope.

The URF and RfC are derived by assuming that an adult weighing 70 kilograms (154 pounds) will breathe 20 m^3 (706 ft^3) of air each day for 365 days a year, over a 70-year lifetime of exposure. This is a standard conversion methodology and is detailed in the RBC table. The excess lifetime cancer risk is calculated for each chemical by multiplying its URF by the average concentration of all the valid air samples collected during the year. The individual risks for each chemical are added to get the total excess lifetime cancer risk at that site. Any risk estimate is based on a number of assumptions and some of the assumptions made for this study include:

- The measured annual average concentration is the concentration that the individual will be exposed to over a lifetime;
- The concentrations measured at the sampling site are representative of exposures to the population in the area;
- The effects from exposure to multiple chemicals are additive;
- The exposure is based on a typical adult;
- The only excess risk considered in this report is due to inhalation.

The non-cancer risk associated with each of the relevant chemicals is calculated by simply dividing the measured air concentration by the chemical's respective RfC. If this value is less than one, and inhalation is the only source of exposure, then that chemical is not likely to cause adverse non-cancer health affects.

Discussion of Results

Tables 2.1, 2.2 and 2.3 summarize the annual average concentrations of volatile organic compounds and the corresponding risks for Chester, Marcus Hook and Swarthmore, respectively. Sampling started at the Chester site in January 1995, at Marcus Hook in April 1995 and at Swarthmore in January 1997. Table 2.4 summarizes the average concentrations for particulates and metals, and the associated excess lifetime cancer risks from inhalation.

The five chemicals with the highest estimated excess lifetime cancer risk are 1,3-butadiene, 1,2-dibromoethane, benzene, vinyl chloride and carbon tetrachloride. With the exception of vinyl chloride at Swarthmore, the estimated excess lifetime cancer risks associated with the metals in Table 2.4 were less than the risks associated with the top five chemicals for all three sites. According to the Agency for Toxic Substances and Disease Registry's Public Health Statement, background carbon tetrachloride concentrations around the world are 0.1 parts per billion. The carbon tetrachloride concentrations at Chester, Marcus Hook and Swarthmore are all at background levels.

The data for Chester, Marcus Hook and Swarthmore also were compared to data collected in and around Baltimore, Maryland and reported to the EPA AIRS database. These data were chosen for comparison because they used the same sampling and analysis methods. Table 2-5 summarizes the Baltimore data. Table 2.6 summarizes the annual average concentrations and associated excess cancer risks for the five highest-risk chemicals.

As was noted earlier, all raw data, including the data used to compile Tables 2-1 through 2-6, are available in Microsoft Excel format.

Table 2.1
Summary of Excess Lifetime Cancer Risks from Inhalation
Across Chemicals of Concern for City of Chester, Pennsylvania

Chemical Name	1/10/95 Through 12/31/95			1/1/96 Through 9/18/96			1/21/97 Through 12/31/97		
	Average Ambient Concentration		Excess Lifetime Cancer Risk	Average Ambient Concentration		Excess Lifetime Cancer Risk	Average Ambient Concentration		Excess Lifetime Cancer Risk
	(ppmv)	(ug/m3)		(ppmv)	(ug/m3)		(ppmv)	(ug/m3)	
1,3-Butadiene	1.03E-04	2.30E-01	6.44E-05	6.91E-05	1.55E-01	4.33E-05	8.12E-05	1.82E-01	5.10E-05
1,2-Dichlorobenzene	1.03E-05	6.25E-02	----------	9.53E-06	5.80E-02	----------	1.35E-05	8.22E-02	----------
1,3-Dichlorobenzene	4.64E-06	2.82E-02	----------	6.55E-07	3.99E-03	----------	2.74E-05	1.67E-01	----------
1,4-Dichlorobenzene	2.42E-05	1.47E-01	9.27E-07	2.96E-05	1.80E-01	1.13E-06	3.67E-05	2.23E-01	1.41E-06
1,2-Dibromoethane	2.20E-05	1.71E-01	3.76E-05	5.49E-06	4.27E-02	9.39E-06	6.32E-06	4.91E-02	1.08E-05
1,1-Dichloroethane	4.67E-06	1.91E-02	----------	3.42E-07	1.40E-03	----------	8.96E-06	3.68E-02	----------
1,2-Dichloroethane	2.10E-05	8.60E-02	2.24E-06	2.76E-05	1.13E-01	2.94E-06	2.91E-05	1.19E-01	3.10E-06
1,1-Dichloroethene	1.25E-05	5.02E-02	2.51E-06	1.16E-06	4.68E-03	2.34E-07	3.64E-06	1.46E-02	7.31E-07
1,2-Dichloropropane	1.57E-05	7.34E-02	----------	9.16E-06	4.29E-02	----------	6.66E-06	3.12E-02	----------
1,3-Dichloropropene	1.15E-05	5.29E-02	1.96E-06	1.64E-07	7.56E-04	2.80E-08	8.94E-06	4.11E-02	1.52E-06
1,1,2,2-Tetrachloroethane	7.38E-06	5.13E-02	2.98E-06	3.27E-06	2.28E-02	1.32E-06	5.78E-06	4.02E-02	2.33E-06
1,2,4-Trichlorobenzene	4.01E-06	3.02E-02	----------	4.76E-06	3.58E-02	----------	8.13E-06	6.11E-02	----------
1,1,1-Trichloroethane	5.48E-04	3.03E+00	----------	1.65E-04	9.09E-01	----------	1.26E-04	6.98E-01	----------
1,1,2-Trichloroethane	8.32E-06	4.59E-02	7.35E-07	1.01E-06	5.60E-03	8.96E-08	7.34E-06	4.06E-02	6.49E-07
1,1,2-Trichloro-1,2,2-Trifluoroethane	1.17E-04	9.05E-01	----------	9.42E-05	0.00E+00 7.31E-01	----------	9.35E-05	7.26E-01	----------
1,2,4-Trimethylbenzene	1.58E-04	7.85E-01	----------	2.09E-04	1.04E+00	----------	2.21E-04	1.10E+00	----------
1,3,5-Trimethylbenzene	5.52E-05	2.75E-01	----------	7.19E-05	3.58E-01	----------	7.19E-05	3.58E-01	----------
Benzene	9.19E-04	2.97E+00	2.47E-05	8.11E-04	2.62E+00	2.18E-05	8.60E-04	2.78E+00	2.31E-05
Bromomethane	3.54E-05	1.39E-01	----------	2.22E-05	8.73E-02	----------	1.81E-05	7.11E-02	----------
Carbon Tetrachloride	1.05E-04	6.68E-01	1.00E-05	1.07E-04	6.82E-01	1.02E-05	1.10E-04	6.99E-01	1.05E-05
Chlorobenzene	1.12E-05	5.22E-02	----------	2.14E-06	9.97E-03	----------	8.79E-06	4.10E-02	----------
Chloroethane	5.74E-05	1.53E-01	----------	7.59E-05	2.03E-01	----------	9.23E-05	2.46E-01	----------
Chloroethene (Vinyl Chlorid	4.59E-05	1.19E-01	1.02E-05	6.64E-05	1.72E-01	1.47E-05	3.34E-05	8.66E-02	7.42E-06
Chloroform	4.39E-05	2.17E-01	5.00E-06	4.14E-05	2.05E-01	4.71E-06	4.51E-05	2.23E-01	5.13E-06
Chloromethane	5.09E-04	1.06E+00	1.82E-06	5.64E-04	1.18E+00	2.02E-06	5.24E-04	1.10E+00	1.88E-06
Dichlorodifluoromethane	6.14E-04	3.08E+00	----------	6.33E-04	3.17E+00	----------	5.74E-04	2.87E+00	----------
Ethylbenzene	1.61E-04	7.08E-01	----------	2.01E-04	8.86E-01	----------	3.96E-04	1.74E+00	----------
Hexachloro-1,3-butadiene	1.25E-05	1.35E-01	2.96E-06	1.97E-06	2.12E-02	4.67E-07	4.13E-06	4.46E-02	9.81E-07
Methylene Chloride	1.83E-04	6.44E-01	3.03E-07	2.26E-04	7.95E-01	3.74E-07	2.82E-04	9.91E-01	4.66E-07
Styrene	4.62E-05	1.99E-01	----------	6.99E-05	3.02E-01	----------	5.44E-05	2.35E-01	----------
Tetrachloroethylene	6.64E-05	4.56E-01	2.60E-07	7.15E-05	4.91E-01	2.80E-07	5.76E-05	3.96E-01	2.26E-07
Toluene	1.85E-03	7.05E+00	----------	1.69E-03	6.46E+00	----------	1.38E-03	5.26E+00	----------
Trichloroethylene	9.75E-05	5.31E-01	9.07E-07	5.91E-05	3.22E-01	5.50E-07	4.76E-05	2.59E-01	4.43E-07
Trichlorofluoromethane	3.07E-04	1.75E+00	----------	3.31E-04	1.88E+00	----------	3.15E-04	1.79E+00	----------
o-Xylene	2.16E-04	9.51E-01	----------	2.35E-04	1.03E+00	----------	4.02E-04	1.77E+00	----------
m,p-Xylene	6.25E-04	2.75E+00	----------	6.08E-04	2.68E+00	----------	1.27E-03	5.59E+00	----------
			1.69E-04			1.14E-04			1.22E-04

Notes: No samples were collected from 9/19/96 to 1/1/97.

Average is the arithmetic mean of all valid samples in the time period with one-half the minimum detection limit substituted for non-detects.

Table 2.2
Summary of Excess Lifetime Cancer Risks from Inhalation
Across Chemicals of Concern for Marcus Hook, Pennsylvania

Chemical Name	4/6/95 Through 12/31/95			1/1/96 Through 12/31/96			1/21/97 Through 12/31/97		
	Average Ambient Concentration		Excess Lifetime Cancer Risk	Average Ambient Concentration		Excess Lifetime Cancer Risk	Average Ambient Concentration		Excess Lifetime Cancer Risk
	(ppmv)	(ug/m3)		(ppmv)	(ug/m3)		(ppmv)	(ug/m3)	
1,3-Butadiene	1.27E-04	2.85E-01	7.97E-05	1.39E-04	3.11E-01	8.71E-05	9.55E-05	2.14E-01	5.99E-05
1,2-Dichlorobenzene	1.15E-04	6.98E-01	----------	1.35E-05	8.21E-02	----------	1.48E-05	8.98E-02	----------
1,3-Dichlorobenzene	4.64E-05	2.82E-01	----------	5.29E-06	3.22E-02	----------	2.14E-05	1.30E-01	----------
1,4-Dichlorobenzene	1.83E-05	1.11E-01	7.01E-07	3.17E-05	1.93E-01	1.21E-06	3.10E-05	1.89E-01	1.19E-06
1,2-Dibromoethane	1.76E-05	1.37E-01	3.01E-05	1.29E-05	1.00E-01	2.21E-05	9.33E-06	7.26E-02	1.60E-05
1,1-Dichloroethane	4.81E-06	1.97E-02	----------	4.81E-06	1.97E-02	----------	6.22E-06	2.55E-02	----------
1,2-Dichloroethane	1.59E-05	6.52E-02	1.70E-06	1.73E-05	7.08E-02	1.84E-06	1.77E-05	7.24E-02	1.88E-06
1,1-Dichloroethene	1.40E-05	5.64E-02	2.82E-06	4.22E-06	1.70E-02	8.48E-07	3.79E-06	1.52E-02	7.61E-07
1,2-Dichloropropane	1.15E-05	5.37E-02	----------	9.97E-06	4.66E-02	----------	5.56E-06	2.60E-02	----------
1,3-Dichloropropene	1.06E-05	4.87E-02	1.81E-06	9.76E-06	4.49E-02	1.66E-06	9.77E-06	4.49E-02	1.67E-06
1,1,2,2-Tetrachloroethane	6.56E-06	4.56E-02	2.64E-06	7.22E-06	5.02E-02	2.91E-06	5.08E-06	3.53E-02	2.05E-06
1,2,4-Trichlorobenzene	4.39E-06	3.30E-02	----------	9.94E-06	7.47E-02	----------	9.66E-06	7.26E-02	----------
1,1,1-Trichloroethane	2.07E-04	1.14E+00	----------	2.02E-04	1.12E+00	----------	1.24E-04	6.86E-01	----------
1,1,2-Trichloroethane	1.68E-05	9.28E-02	1.48E-06	8.92E-06	4.93E-02	7.89E-07	8.41E-06	4.65E-02	7.43E-07
1,1,2-Trichloro-1,2,2-Trifluoroethane	1.39E-04	1.08E+00	----------	1.06E-04	8.20E-01	----------	9.88E-05	7.67E-01	----------
1,2,4-Trimethylbenzene	2.03E-04	1.01E+00	----------	2.49E-04	1.24E+00	----------	2.21E-04	1.10E+00	----------
1,3,5-Trimethylbenzene	7.32E-05	3.64E-01	----------	8.45E-05	4.21E-01	----------	7.41E-05	3.69E-01	----------
Benzene	8.97E-04	2.90E+00	2.41E-05	8.14E-04	2.63E+00	2.18E-05	8.31E-04	2.69E+00	2.23E-05
Bromomethane	1.25E-05	4.93E-02	----------	1.86E-05	7.30E-02	----------	1.93E-05	7.60E-02	----------
Carbon Tetrachloride	1.03E-04	6.54E-01	9.81E-06	1.05E-04	6.71E-01	1.01E-05	1.05E-04	6.71E-01	1.01E-05
Chlorobenzene	2.24E-05	1.04E-01	----------	6.29E-06	2.93E-02	----------	7.88E-06	3.67E-02	----------
Chloroethane	4.55E-05	1.22E-01	----------	5.44E-05	1.45E-01	----------	5.03E-05	1.34E-01	----------
Chloroethene (Vinyl Chlorid	6.09E-05	1.58E-01	1.35E-05	4.12E-05	1.07E-01	9.15E-06	3.51E-05	9.07E-02	7.77E-06
Chloroform	3.09E-05	1.53E-01	3.52E-06	3.25E-05	1.60E-01	3.69E-06	3.10E-05	1.53E-01	3.53E-06
Chloromethane	5.29E-04	1.11E+00	1.89E-06	6.26E-04	1.31E+00	2.24E-06	5.72E-04	1.20E+00	2.04E-06
Dichlorodifluoromethane	6.47E-04	3.24E+00	----------	6.32E-04	3.16E+00	----------	5.78E-04	2.89E+00	----------
Ethylbenzene	2.24E-04	9.83E-01	----------	2.91E-04	1.28E+00	----------	3.02E-04	1.33E+00	----------
Hexachloro-1,3-butadiene	1.11E-05	1.20E-01	2.64E-06	9.45E-06	1.02E-01	2.24E-06	5.07E-06	5.47E-02	1.20E-06
Methylene Chloride	1.80E-04	6.33E-01	2.97E-07	2.41E-04	8.46E-01	3.98E-07	2.46E-04	8.66E-01	4.07E-07
Styrene	6.98E-05	3.01E-01	----------	7.87E-05	3.40E-01	----------	7.37E-05	3.18E-01	----------
Tetrachloroethylene	4.80E-05	3.30E-01	1.88E-07	6.01E-05	4.13E-01	2.36E-07	5.45E-05	3.74E-01	2.14E-07
Toluene	3.31E-03	1.26E+01	----------	3.90E-03	1.49E+01	----------	2.26E-03	8.63E+00	----------
Trichloroethylene	6.51E-05	3.54E-01	6.06E-07	3.02E-05	1.64E-01	2.81E-07	2.59E-05	1.41E-01	2.41E-07
Trichlorofluoromethane	3.06E-04	1.74E+00	----------	3.37E-04	1.92E+00	----------	3.03E-04	1.72E+00	----------
o-Xylene	3.29E-04	1.45E+00	----------	3.14E-04	1.38E+00	----------	3.53E-04	1.55E+00	----------
m,p-Xylene	1.08E-03	4.76E+00	----------	9.83E-04	4.32E+00	----------	1.05E-03	4.61E+00	----------
			1.77E-04			1.69E-04			1.32E-04

Note: Average is the arithmetic mean of all valid samples in the time period with one-half the minimum detection limit substituted for non-detects.

Table 2.3

Summary of Excess Lifetime Cancer Risks from Inhalation Across Chemicals of Concern for Swarthmore, Pennsylvania

	1/21/97 Through 12/31/97		
Chemical Name	**Average Ambient Concentration**		**Excess Lifetime Cancer Risk**
	(ppmv)	**(ug/m3)**	
1,3-Butadiene	6.99E-05	1.57E-01	4.39E-05
1,2-Dichlorobenzene	1.06E-05	6.43E-02	----------
1,3-Dichlorobenzene	2.48E-05	1.51E-01	----------
1,4-Dichlorobenzene	2.82E-05	1.72E-01	1.08E-06
1,2-Dibromoethane	7.82E-06	6.09E-02	1.34E-05
1,1-Dichloroethane	7.98E-06	3.27E-02	----------
1,2-Dichloroethane	1.47E-05	6.02E-02	1.57E-06
1,1-Dichloroethene	3.47E-06	1.39E-02	6.96E-07
1,2-Dichloropropane	5.73E-06	2.68E-02	----------
1,3-Dichloropropene	9.35E-06	4.30E-02	1.59E-06
1,1,2,2-Tetrachloroethane	1.56E-05	1.08E-01	6.28E-06
1,2,4-Trichlorobenzene	8.79E-06	6.60E-02	----------
1,1,1-Trichloroethane	1.37E-04	7.57E-01	----------
1,1,2-Trichloroethane	7.16E-06	3.95E-02	6.33E-07
1,1,2-Trichloro-1,2,2-Trifluoroethane	8.71E-05	6.76E-01	----------
Benzene	3.67E-04	1.19E+00	9.86E-06
Bromomethane	1.90E-05	7.46E-02	----------
Carbon Tetrachloride	1.09E-04	6.95E-01	1.04E-05
Chlorobenzene	6.10E-06	2.84E-02	----------
Chloroethane	2.08E-05	5.55E-02	----------
Chloroethene (Vinyl Chloride)	1.48E-05	3.82E-02	3.27E-06
Chloroform	3.10E-05	1.53E-01	3.52E-06
Chloromethane	5.23E-04	1.09E+00	1.87E-06
Dichlorodifluoromethane	5.90E-04	2.95E+00	----------
Ethylbenzene	1.13E-04	4.98E-01	----------
Hexachloro-1,3-butadiene	4.33E-06	4.67E-02	1.03E-06
Methylene Chloride	1.89E-04	6.66E-01	3.13E-07
Styrene	3.06E-05	1.32E-01	----------
Tetrachloroethylene	5.53E-05	3.80E-01	2.17E-07
Toluene	7.81E-04	2.98E+00	----------
Trichloroethylene	2.53E-04	1.38E+00	2.36E-06
Trichlorofluoromethane	3.83E-04	2.18E+00	----------
o-Xylene	1.31E-04	5.75E-01	----------
m,p-Xylene	3.41E-04	1.50E+00	----------
			1.02E-04

Note: Average is the arithmetic mean of all valid samples in the time period with one-half the minimum detection limit substituted for non-detects.

Table 2.4
Summary of Excess Lifetime Cancer Risks from Inhalation for Metals

Chester

Chemical Name	Average Concentration ug/m^3	Maximum Concentration ug/m^3	Minimum Concentration ug/m^3	Standard Deviation	Excess Lifetime Cancer Risk	Reference Concentration ug/m^3	Unit Risk Factor m^3/ug
Arsenic	1.12E-03	2.49E-03	2.18E-04	5.16E-04	4.80E-06	----------	4.30E-03
Beryllium	4.78E-05	5.52E-05	3.68E-05	4.24E-06	1.15E-07	2.00E-02	2.40E-03
Cadmium	2.93E-04	1.35E-03	1.10E-04	2.43E-04	5.28E-07	----------	1.80E-03
Chromium	3.92E-03	1.25E-02	9.29E-04	2.72E-03	----------	----------	----------
Hexavalent Chromium[1]	6.38E-05	ND	ND	3.20E-06	7.66E-07	3.50E-04	1.20E-02
Lead	1.35E-02	2.64E-02	6.46E-03	4.44E-03	----------	9.00E-02	----------
Nickel[2]	5.72E-03	1.56E-02	1.93E-03	3.19E-03	1.37E-06	----------	2.40E-04
Zinc	4.50E-02	1.42E-01	1.66E-02	3.14E-02	----------	----------	----------
Particulate Matter (TSP)	5.60E+01	1.11E+02	1.89E+01	2.32E+01	----------	----------	----------
PM-10[3]	3.16E+01	7.23E+01	1.09E+01	1.31E+01	----------	5.00E+01	----------
					7.58E-06		

Marcus Hook

Arsenic	9.01E-04	1.62E-03	1.70E-04	3.81E-04	3.87E-06	----------	4.30E-03
Beryllium	4.45E-05	4.80E-05	3.98E-05	2.19E-06	1.07E-07	2.00E-02	2.40E-03
Cadmium	2.12E-04	4.70E-04	6.88E-05	9.37E-05	3.82E-07	----------	1.80E-03
Chromium	2.28E-03	3.79E-03	8.49E-04	9.57E-04	----------	----------	----------
Hexavalent Chromium[1]	5.78E-05	ND	ND	1.52E-06	6.94E-07	3.50E-04	1.20E-02
Lead	1.09E-02	2.37E-02	4.14E-03	4.79E-03	----------	9.00E-02	----------
Nickel[2]	6.24E-03	3.98E-02	1.73E-03	6.33E-03	1.50E-06	----------	2.40E-04
Zinc	3.57E-02	1.38E-01	1.35E-02	2.44E-02	----------	----------	----------
Particulate Matter (TSP)	3.08E+01	6.58E+01	1.45E+01	1.05E+01	----------	5.00E+01	----------
PM-10[3]	2.31E+01	6.22E+01	1.01E+01	1.05E+01	----------	----------	----------
					6.55E-06		

Swarthmore

Arsenic	7.73E-04	1.58E-03	1.84E-04	3.50E-04	3.32E-06	----------	4.30E-03
Beryllium	4.98E-05	1.06E-04	4.37E-05	9.20E-06	1.20E-07	2.00E-02	2.40E-03
Cadmium	1.75E-04	3.85E-04	4.60E-05	7.81E-05	3.14E-07	----------	1.80E-03
Chromium	1.71E-03	4.16E-03	9.10E-04	8.64E-04	----------	----------	----------
Hexavalent Chromium[1]	6.44E-05	ND	ND	2.34E-06	7.73E-07	3.50E-04	1.20E-02
Lead	8.98E-03	2.53E-02	4.48E-03	3.64E-03	----------	9.00E-02	----------
Nickel[2]	3.39E-03	9.79E-03	1.12E-03	1.88E-03	8.13E-07	----------	2.40E-04
Zinc	2.76E-02	9.02E-02	1.16E-02	1.47E-02	----------	----------	----------
Particulate Matter (TSP)	2.84E+01	6.02E+01	1.25E+01	9.83E+00	----------	5.00E+01	----------
PM-10[3]	2.09E+01	5.71E+01	9.84E+00	9.82E+00	----------	----------	----------
					5.34E-06		

Notes: 1. Hexavalent chromium (Cr^{VI+}) was not detected in any sample. The excess cancer risk from inhalation is for one-half the minimum detection limit. The MDL varies with the sampler flow rate.
2. The URF is for nickel as refinery dust.
3. The RfC is the annual mean ambient air quality standard.

Table 2.5
Summary of Excess Lifetime Cancer Risks from Inhalation Across Chemicals of Concern for Baltimore, Maryland-area Sites Reported on AIRS

Chemical Name	1995 Average Ambient Concentration (ppmv)	1995 Average Ambient Concentration (ug/m3)	1995 Excess Lifetime Cancer Risk	1996 Average Ambient Concentration (ppmv)	1996 Average Ambient Concentration (ug/m3)	1996 Excess Lifetime Cancer Risk	1997 Average Ambient Concentration (ppmv)	1997 Average Ambient Concentration (ug/m3)	1997 Excess Lifetime Cancer Risk
1,3-Butadiene	1.89E-04	4.24E-01	1.19E-04	1.55E-04	3.47E-01	9.71E-05	1.42E-04	3.17E-01	8.88E-05
1,2-Dibromoethane	1.39E-05	1.08E-01	2.38E-05	1.22E-05	9.50E-02	2.09E-05	1.35E-05	1.05E-01	2.31E-05
1,2-Dichloroethane	2.70E-05	1.11E-01	2.88E-06	1.14E-05	4.66E-02	1.21E-06	1.28E-05	5.23E-02	1.36E-06
1,1-Dichloroethene	1.29E-05	5.16E-02	2.58E-06	5.00E-06	2.01E-02	1.00E-06	5.50E-06	2.21E-02	1.10E-06
1,3-Dichloropropene	na	na	na	na	na	na	na	na	na
1,1,2,2-Tetrachloroethane	1.19E-05	8.29E-02	4.81E-06	1.45E-05	1.01E-01	5.85E-06	2.28E-05	1.58E-01	9.17E-06
1,1,2-Trichloroethane	2.09E-05	1.15E-01	1.84E-06	1.00E-05	5.52E-02	8.84E-07	1.02E-05	5.66E-02	9.06E-07
Benzene	7.08E-04	2.29E+00	1.90E-05	7.35E-04	2.38E+00	1.97E-05	6.21E-04	2.01E+00	1.67E-05
Carbon Tetrachloride	1.04E-04	6.64E-01	9.96E-06	1.17E-04	7.46E-01	1.12E-05	1.23E-04	7.86E-01	1.18E-05
Chloroethene (Vinyl Chloride)	1.76E-05	4.57E-02	3.91E-06	1.21E-05	3.14E-02	2.69E-06	1.08E-05	2.80E-02	2.40E-06
Chloroform	3.87E-05	1.91E-01	4.40E-06	4.61E-05	2.28E-01	5.25E-06	3.82E-05	1.89E-01	4.34E-06
Chloromethane	4.85E-04	1.02E+00	1.83E-06	5.50E-04	1.15E+00	2.07E-06	3.64E-04	7.61E-01	1.37E-06
Hexachloro-1,3-butadiene	1.00E-05	1.08E-01	2.38E-06	1.19E-05	1.29E-01	2.83E-06	1.06E-05	1.14E-01	2.51E-06
Methylene Chloride	2.23E-04	7.83E-01	3.68E-07	2.84E-04	1.00E+00	4.70E-07	3.72E-04	1.31E+00	6.14E-07
Tetrachloroethylene	1.17E-04	8.00E-01	4.64E-07	1.33E-04	9.11E-01	5.28E-07	8.98E-05	6.17E-01	3.58E-07
Trichloroethylene	7.13E-04	3.88E+00	6.64E-06	6.51E-05	3.54E-01	6.06E-07	3.80E-05	2.07E-01	3.54E-07
			2.04E-04			1.72E-04			1.65E-04

Notes: No data available for 1,3-Dichloropropene
AIRS is the EPA's Aerometric Information and Retrieval System Database

Table 2.6
Comparison of Annual Average Concentrations and Inhalation Cancer Risks at Chester to Other Sites

1995								
	Chester		Marcus Hook		Swarthmore		Baltimore	
	ppbv	Risk	ppbv	Risk	ppbv	Risk	ppbv	Risk
1,3-Butadiene	0.103	6.44E-05	0.127	7.97E-05	-	-	0.189	1.19E-04
1,2-Dibromoethane	0.022	3.76E-05	0.018	3.01E-05	-	-	0.014	2.38E-05
Benzene	0.919	2.47E-05	0.897	2.41E-05	-	-	0.708	1.90E-05
Carbon Tetrachloride	0.105	1.00E-05	0.103	9.81E-06	-	-	0.104	9.96E-06
Chloroethene (Vinyl Chloride)	0.046	1.02E-05	0.061	1.35E-05	-	-	0.018	3.91E-06
Total for compounds in Table 2.1		1.69E-04		1.77E-04		-		2.04E-04

1996								
	Chester		Marcus Hook		Swarthmore		Baltimore	
	ppbv	Risk	ppbv	Risk	ppbv	Risk	ppbv	Risk
1,3-Butadiene	0.069	4.33E-05	0.139	8.71E-05	-	-	0.155	9.71E-05
1,2-Dibromoethane	0.005	9.39E-06	0.013	2.21E-05	-	-	0.012	2.09E-05
Benzene	0.811	2.18E-05	0.814	2.18E-05	-	-	0.735	1.97E-05
Carbon Tetrachloride	0.107	1.02E-05	0.105	1.01E-05	-	-	0.117	1.12E-05
Chloroethene (Vinyl Chloride)	0.066	1.47E-05	0.041	9.15E-06	-	-	0.012	2.69E-06
Total for compounds in Table 2.1		1.14E-04		1.69E-04		-		1.72E-04

1997								
	Chester		Marcus Hook		Swarthmore		Baltimore	
	ppbv	Risk	ppbv	Risk	ppbv	Risk	ppbv	Risk
1,3-Butadiene	0.081	5.10E-05	0.095	5.99E-05	0.070	4.39E-05	0.142	8.88E-05
1,2-Dibromoethane	0.006	1.08E-05	0.009	1.60E-05	0.008	1.34E-05	0.014	2.31E-05
Benzene	0.860	2.31E-05	0.831	2.23E-05	0.367	9.86E-06	0.621	1.67E-05
Carbon Tetrachloride	0.110	1.05E-05	0.105	1.01E-05	0.109	1.04E-05	0.123	1.18E-05
Chloroethene (Vinyl Chloride)	0.033	7.42E-06	0.035	7.77E-06	0.015	3.27E-06	0.011	2.40E-06
Total for compounds in Table 2.1		1.22E-04		1.32E-04		1.02E-04		1.65E-04

Notes:

Baltimore - Combined annual averages for the greater Baltimore, Maryland-area sites reported in AIRS.
Swarthmore sampling started January 22, 1997.
Totals are the sum of the inhalation cancer risks for all compounds listed in Tables 2.1, 2.2 and 2.3.

Appendix

Explanation of Scientific Notation

Scientific notation is used throughout this study to express numbers smaller than zero.

For example,

1.00 E-01 = $1.00x10^{-1}$ = 0.1 (one in ten)

1.00 E-02 = 1.00×10^{-2} = 0.01 (one in a hundred)

1.00 E-03 = 1.00×10^{-3} = 0.001 (one in a thousand)

1.00 E-04 = 1.00×10^{-4} = 0.0001 (one in ten thousand)

1.00 E-05 = 1.00×10^{-5} = 0.00001 (one in a hundred thousand)

1.00 E-06 = 1.00×10^{-6} = 0.000001 (one in million)

1.00 E-07 = 1.00×10^{-7} = 0.0000001 (one in ten million)

1.00 E-08 = 1.00×10^{-8} = 0.00000001 (one in a hundred million)

1.00 E-09 = 1.00×10^{-9} = 0.000000001 (one in a billion)

Using the above conversions, 1.98 E-06 is equivalent to 0.00000198 (1.98 in a million).

Definitions

Air basin — A geographic area of the Commonwealth of Pennsylvania as defined in 25 PA Code § 121.1. The Southeast Pennsylvania air basin includes the counties of Bucks, Chester, Delaware, Montgomery and Philadelphia.

AIRS —Aerometric Information and Retrieval System is EPA's national database of air quality information. The Air Quality Subsystem (AQS) contains data on ambient air measurements.

Blank – Sampling materials and chemicals analyzed without collecting a sample to test for contaminants that might interfere with the analysis. The analytical protocol specifies acceptable blank levels and how these values are used in calculating the results.

Chronic — Occurring over a long period of time. Cancer is the primary health effect considered when evaluating the risk from chronic exposure to a chemical compound.

Excess risk — An increased risk of disease above the normal background rate.

Halogenated — A chemical compound containing fluorine, chlorine, bromine or iodine.

Mean — The arithmetic average. For example, (2.2 +2.6 +4.8)/3 = 3.2.

Micron — A unit of length equal to one millionth of a meter or about 0.0000394 inches.

Microgram per cubic meter — A microgram is one millionth of a gram weight. (The symbol ug is commonly used for microgram because mg is used for milligram, one thousandth of a gram.) Ambient air concentrations are commonly expressed in micrograms per cubic meter of air (ug/m^3). Because air expands and contracts with changes in temperature and pressure, the cubic meter volume must be referenced to a specific temperature and pressure. Standard conditions for ambient air measurements are 25° C (77° F) and one atmosphere (29.92 inches of mercury).

Nanogram — One billionth of a gram weight. Very low ambient air concentrations are expressed in nanograms per cubic meter of air (ng/m^3).

PAMS — Photochemical Assessment Monitoring Stations measure certain compounds that react in sunlight leading to the formation of ground-level ozone.

Particulate matter — A material except uncombined water, which is or has been airborne and exists as a solid or liquid at 70° F and standard atmospheric pressure.

ppbC — Parts per billion Carbon are the concentration units normally used by EPA for PAMS hydrocarbon pollutants in ambient air. To convert ppbv to ppbC, multiply the concentration in ppbv by the number of carbon atoms in the compound.

ppbv — Parts per billion by volume are the concentration units commonly used for gaseous pollutants in ambient air. These units do not have any meaning for non-gaseous pollutants.

PM-10 — Particulate matter with an effective aerodynamic diameter of less than or equal to a nominal 10 micron body as measured by the applicable reference method or an equivalent method. For practical purposes, these are the particles in the air that are small enough to be inhaled. Recent EPA regulations also cover PM-2.5, even smaller particles that can penetrate deeper into the lungs.

Unit Risk Factor (URF) — A measure of the probability of an individual developing cancer as a result of exposure to a specified unit ambient concentration of a specific chemical. In air, the unit concentration is 1.0 microgram per cubic meter. For example, an inhalation URF of 3.0E-04 implies that if 10,000 people breathe that chemical for 70 years at a concentration of 1.0 ug/m^3, three of the 10,000 may develop cancer as a result of the exposure.

Volatile organic — A chemical containing carbon that can exist in the atmosphere as a gas at normal temperatures. Generally, these are chemicals with vapor pressures greater than 0.1 mmHg (0.0001316 atmospheres) at 70° F.

Site Locations

Approximate locations taken from U. S. Geological Survey 7.5° Quadrangles

Chester	N 39° 49' 45", W 75° 23' 18"
Marcus Hook	N 39° 49' 04", W 75° 24' 51"
Swarthmore	N 39° 53' 49", W 75° 21' 14"
Chester COPAMS	N 39° 50' 08", W 75° 22' 22"

Risk Calculation

The excess lifetime cancer risk for each of the chemicals was calculated by using EPA's unit risk factors (URFs). The EPA Region III Superfund Technical Support Section has established a risk-based concentration (RBC) table for nearly 500 chemicals. Four different chronic toxicological constants are examined for each chemical compound: 1) Oral Reference Dose (RfDo); 2) Inhalation Reference Dose (RfDi); 3) Oral Cancer Potency Slope (CPSo); and 4) Inhalation Cancer Potency Slope (CPSi). The sources of the toxicological constants are: 1) the Integrated Risk Information System (IRIS); 2) Health Effects Assessment Summary Tables (HEAST); 3) HEAST Alternate; 4) EPA-NCEA Regional Support Provisional Value; and 5) other EPA documents. For this study, only the RfDi and CPSi were used. In some cases, there were no inhalation risk data for the chemicals in the RBC table, so other sources, such as the Boilers and Industrial Furnaces (BIF) Regulation, had to be referenced.

The URF and the reference air concentration (RfC) are derived from the CPSi and RfDi, respectively, by assuming that an adult weighing 70 kilograms (154 pounds) will breathe 20 m^3 (706 ft^3) of air a day for 365 days a year, over a 70-year lifetime of exposure. This is a standard conversion methodology and is detailed on page two of the "Contents, Uses, and Limitations of the RBC Table" section of the RBC table. From this standard 70-year exposure scenario for an adult, excess lifetime cancer risk is calculated for each chemical by multiplying the measured air concentrations by their respective URFs. The individual risks for each chemical are added to get the total excess lifetime cancer risk at that site. The non-cancer risk associated with each of the relevant chemicals is calculated by simply dividing the measured air concentration by the chemical's respective RfC.

The conversion from CPSi to URF is carried out as follows:

$$(\text{kg-day})/\text{mg} \times (1/70\ \text{kg}) \times (20\ m^3/\text{day}) \times (\text{mg}/1000\ \text{ug}) = m^3/\text{ug}$$

The conversion from RfDi to RfC is carried out as follows:

$$\text{mg}/(\text{kg-day}) \times (70\ \text{kg}) \times (\text{day}/20\ m^3) \times (1000\ \text{ug}/\text{mg}) = \text{ug}/m^3$$

Changes in URFs and RfCs from the First Interim Report

- 1,2-Dichlorobenzene – RfC changed from 1.40E+02 to 3.15E+01 (change in EPA-NCEA)
- 1,3-Dichlorobenzene – RfC added (change in EPA-NCEA)
- 1,4-Dichlorobenzene – URF added (change in EPA-NCEA)
- 1,2-Dichoroethane – RfC changed from 1.00E+01 to 4.90E+00 (change in EPA-NCEA)
- 1,2-Dichloropropane – URF deleted (supporting documentation not adequate)
- Chlorobenzene – RfC changed from 2.00E+01 to 1.75E+01 (change in HEAST Alternate)
- Chloroethene – URF changed from 8.40E-05 to 8.57E-05 (change in HEAST)
- Chloroform – RfC added (change in EPA-NCEA)
- Dichlorodifluoromethane – RfC changed from 2.00E+02 to 1.75E+02 (change in HEAST Alternate)
- Tetrachloroethylene – RfC changed from 8.10E+01 to 4.90E+02 (change in EPA-NCEA)
- 1,2,4-Trimethylbenzene – RfC added (change in EPA-NCEA)
- 1,3,5-Trimethylbenzene – RfC added (change in EPA-NCEA)

Table A.1 Unit Risk Factors and Reference Concentrations Used for the Air Monitoring Study Risk Assessment

Chemical Name	Unit Risk (m3/ug)	Reference Air Concentration (ug/m3)	Source Codes
1,3-Butadiene	2.80E-04	--------	**I**
1,2-Dichlorobenzene	--------	3.15E+01	**O**
1,3-Dichlorobenzene	--------	7.00E+00	**O**
1,4-Dichlorobenzene	6.29E-06	8.00E+02	**O, I**
1,2-Dibromoethane	2.20E-04	2.00E-01	**O, I**
1,1-Dichloroethane	--------	5.00E+02	**O**
1,2-Dichloroethane	2.60E-05	4.90E+00	**I,O**
1,1-Dichloroethene	5.00E-05	--------	**I**
1,2-Dichloropropane	--------	4.00E+00	**I**
1,3-Dichloropropene	3.71E-05	2.00E+01	**O, I**
1,1,2,2-Tetrachloroethane	5.80E-05	--------	**I**
1,2,4-Trichlorobenzene	--------	2.00E+02	**O**
1,1,1-Trichloroethane	--------	1.00E+03	**O**
1,1,2-Trichloroethane	1.60E-05	--------	**I**
1,1,2-Trichloro-1,2,2-Trifluoroethane	--------	3.00E+04	**O**
1,2,4-Trimethylbenzene	--------	6.00E+00	**O**
1,3,5-Trimethylbenzene	--------	6.00E+00	**O**
Benzene	8.30E-06	6.00E+00	**I, O**
Bromomethane	--------	5.00E+00	**I**
Carbon Tetrachloride	1.50E-05	2.00E+00	**I,O**
Chlorobenzene	--------	1.75E+01	**O**
Chloroethane	--------	1.00E+04	**I**
Chloroethene (Vinyl Chloride)	8.57E-05	--------	**O**
Chloroform	2.30E-05	3.00E-01	**I, O**
Chloromethane	1.80E-06	--------	**O**
Dichlorodifluoromethane	--------	1.75E+02	**O**
Ethylbenzene	--------	1.00E+03	**I**
Hexachloro-1,3-butadiene	2.20E-05	--------	**I**
Methylene Chloride	4.70E-07	3.00E+03	**I, O**
Styrene	--------	1.00E+03	**I**
Tetrachloroethylene	5.80E-07	4.90E+02	**O, O**
Toluene	--------	4.00E+02	**I**
Trichloroethylene	1.71E-06	3.00E+02	**O, O**
Trichlorofluoromethane	--------	7.00E+02	**O**
o-Xylene	--------	8.00E+01	**B**
m,p-Xylene	--------	8.00E+01	**B**
Arsenic	4.30E-03	--------	**I**
Beryllium	2.40E-03	2.00E-02	**I, I**
Cadmium	1.80E-03	--------	**I**
Hexavalent Chromium	1.20E-02	3.50E-04	**I,O**
Lead	--------	9.00E-02	**B**
Nickel	2.40E-04	--------	**I**

I U.S. EPA's Integrated Risk Information System (IRIS)
B Boiler and Industrial Furnace Regulations (BIF)
O Other sources .