FINAL

Emissions Comparison: Continuous Drum Asphalt Plant and Selected Source Categories

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Report Prepared for:

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1.0 INTRODUCTION

Background

At the request of the National Asphalt Pavement Association (NAPA), Clayton Group Services, Incorporated (Clayton) conducted a study to compare air emissions from a certain type of hot mix asphalt plant (continuous drum) against air emissions from other easily recognizable, consumer-oriented source categories. In December of 2000, Clayton summarized the results of a previous study for NAPA comparing emissions from a batch asphalt plant against these same source categories. The goal of this effort has been to assist member NAPA companies in understanding the magnitude of emissions from asphalt plants relative to atmospheric releases from sources commonly found within a given community. The NAPA leadership believes that such an understanding will be useful for members engaged in community discussions on local environmental issues.

The benchmark for this evaluation was a typical continuous drum hot mix asphalt plant, which we defined as having an annual production rate of 200,000 tons. As with Clayton's previous study, six other categories of air pollution sources were examined:

- Residential fireplaces,
- Residential woodstoves,
- Bakeries,
- Gasoline filling stations,
- Barbeque grills, and
- Fast-food restaurants.

Clayton selected these six categories because of their frequent occurrence in most communities and the reasonably good availability of emissions data with which to compare against emissions from asphalt plants.

Clayton's methodology for the study involved several steps. First, we calculated emissions from our predetermined "typical" hot mix asphalt plant. We then selected candidate source categories and conducted literature searches to identify emission factors and activity data. Finally, we used the emission factors and activity data for each category to determine annual emissions that were comparable to emissions from a typical asphalt plant. In deriving annual emission estimates for each source category, we attempted to develop a number that was similar to the emission levels from our typical plant. That approach in essence shows the number of sources in each category that would have emissions comparable to emissions from an asphalt plant (for example: thirteen residential fireplaces, twelve gas filling stations, twenty-seven fast-food restaurants).

To acquire data for the analysis, Clayton conducted information searches through the U.S. Environmental Protection Agency's (EPA's) Clearinghouse for Inventories and Emission Factors (CHIEF) on the EPA Technology Transfer Network, EPA's home page information sources function, California South Coast Air Quality Management District home page information sources function, and the EPA Research Triangle Park library. Where possible, we tried to use EPA references (such as AP-42 document sections, Locating & Estimating documents, and other laboratory research reports) to enhance the credibility of our results. These references tend to base emission estimates on a larger data set than would a journal article or a State-sponsored emissions study.

Executive Summary

The results of our study show that emissions from a continuous drum hot mix asphalt plant are generally within the range of a small number of emissions sources from several consumer-oriented source categories. The following scenarios represent emission levels that are comparable to annual releases from a typical hot mix asphalt plant:

- VOC emissions from 13 residential fireplaces during the course of one year
- VOC emissions from one bakery operating for about two weeks
- TOC emissions from 12 gas filling stations during the course of one year

- TOC emissions from 27 fast-food restaurants during the course of one year
- Total PAH emissions from 35 residential woodstoves
- Benzene emissions from one gas filling station operating for seven months
- Toluene emissions from one gas filling station operating for five months
- Xylene emissions from 1.5 gas filling stations operating during the course of one year

2.0 *EMISSION ESTIMATES*

Clayton developed emission estimates for each source category by combining emission factors with reasonably available activity data (throughput, consumption, etc.). With one exception, emission factors for the various source categories were obtained from EPA publications and were based on multiple source measurements. The one exception was our selected emission factor for fast food restaurants, which came from a peer-reviewed journal and was based on data from one source test.

Table 1 (located at the end of this report) presents the emission factors by pollutant for each source category Clayton evaluated in this study. The full citations for each report and journal article used by Clayton are listed in Section 5.0 of this report. A general description of the reference for each category is listed below.

- Hot Mix Asphalt Plants – EPA Office of Air Quality Planning & Standards AP-42 Document [1]
- Residential Fireplaces – EPA Office of Air Quality Planning & Standards AP-42 Document [2]
- Residential Woodstoves – EPA Office of Air Quality Planning & Standards AP-42 Document [3]
- Bakeries – EPA Office of Air Quality Planning & Standards AP-42 Document [4]
- Barbecue Grills – EPA Air & Energy Engineering Research Laboratory Report [5]
- Lawn Mowers – EPA Office of Mobile Sources Engine and Vehicle Emissions Study Report [6]
- Gasoline Filling Stations – EPA Locating & Estimating (L&E) Documents for Benzene, Toluene, and Xylene (3 reports) [7,8,9]
- Fast Food Restaurants – *Environmental Science & Technology* Journal Article [10]

In general, the activity information for each source category was derived using a combination of data and engineering estimates. The one exception was our gasoline-refueling category. For this category, the activity data (i.e., throughput amount) was based solely on the average amount of gasoline calculated from EPA studies, as reported in the EPA's L&E documents.

Tables 2 through 9 (located at the end of this report) provide the emission calculations and engineering assumptions for the annual estimates associated with each category. A brief overview on the emissions derivation assumptions for each category is presented below.

Residential Fireplaces & Woodstoves

The emission factor for both wood-burning categories was expressed as tons (per year) per tons of wood used. Clayton obtained the average wood use per household from an EPA-sponsored study. [11] The wood consumption value was expressed as mass quantity of wood per heating degree-days (HDD). We assumed that the average number of HDD throughout the nation is about one-third the value reported in Reference 11 for the Northeast.

Bakeries

The emissions factor for bakeries was an equation with several variables, which yields pound of pollutant per ton of baked bread. The numbers Clayton used for each variable in the emissions equation were obtained from an EPA reference listed values for different oven sizes. Clayton selected variables associated with an oven with medium-sized production. [12]

Barbeque Grills

The emission factor for barbeque grills was expressed as pound of pollutant per minute of cooking time. Clayton employed technical judgment to determine the average cooking time and number of times per year of barbeque usage.

Lawn Mowers

The emission factor for lawn mowers was expressed as pound of pollutant per horsepower-hour. The EPA reference which provided the emission factor was also used to identify average horsepower rating and average hours per year of usage.

Auto Refueling

The emission factor for gas station refueling was expressed as pound of pollutant per gallon of fuel consumed. The average fuel consumption per gas station was obtained from the EPA reference from which the emission factor was obtained.

Fast-Food Restaurants

The emission factor for fast-food restaurants was expressed as milligram of pollutant per kilogram of meat cooked. Clayton determined the average annual meat consumption by contacting the Holdings Group for a local fast-food restaurant chain.

3.0 COMPARISON OF AIR EMISSION ESTIMATES

Clayton developed a comparison of air pollution emissions for the various source categories based on specific pollutants or groups of pollutants. The list of pollutants for the comparison included:

- Total Organic Compounds (TOC),
- Volatile Organic Compounds (VOC),
- Particulate Matter (PM),
- Toluene,
- Benzene,
- Polycyclic Aromatic Hydrocarbons (PAHs)
- Benzo(b)fluoranthene
- Benzo(a)pyrene
- Fluoranthene, and
- Pyrene.

The phrase "total organic compounds" is a generic term, referring to any compound containing a carbon atom. Volatile organic compounds (VOCs) are essentially all organic compounds that contribute appreciably to the formation of tropospheric ozone. The term VOC includes most organic compounds except methane, ethane, and a handful of halogenated compounds that have a neglible effect on ozone formation.

Another group of air pollution compounds are classified as hazardous air pollutants (HAPs) and are regulated by the EPA under Title III of the Clean Air Act. Of the 189, benzene, toluene, xylene, and selected PAH's were used for comparison. These HAPs were selected since three of the sources had published emission factors for these compounds.

Table 10 (located at the end of this report) presents emissions comparisons between a typical hot mix asphalt plant and several source categories. The information is presented in such a way to allow the reader to understand the amount of emissions from an asphalt plant relative to other consumer-oriented source categories.

4.0 CONCLUSIONS

Emissions from hot mix asphalt plants are comparable to many consumer-oriented source categories for a number of pollutants. A useful comparison of air emissions can be based on either the VOC or TOC emissions, since all the sources reported either TOC or VOC. The VOC emissions from a "typical" hot mix asphalt plant are approximately the same as those from about a dozen residential fireplaces and an order of magnitude less than those from a bread bakery. Furthermore, the TOC emissions from a typical hot mix asphalt plant are comparable to common residential emission sources from a small neighborhood. For TOC, the equivalent emission levels ranged from 12 gasoline filling stations to 382 residential woodstoves burning wood throughout the heating season.

Particulate emissions from a typical asphalt plant had the largest emissions compared to other sources. However, even the PM emissions were comparable to those from a neighborhood with about 90 fireplaces or 160 woodstoves.

It was difficult to develop a comparison of emissions for PAHs because not all of the same PAH species were reported for each source category. However, it is significant to note that the speciated PAHs emissions from our "typical" hot mix asphalt plant were generally lower than the same PAH species for the other sources investigated.

5.0 REFERENCES

1. U.S. Environmental Protection Agency. AP-42. Section 11.1 – Hot Mix Asphalt Plants. (DRAFT)

2. U.S. Environmental Protection Agency. AP-42. Section 1.9 – Residential Fireplaces

3. U.S. Environmental Protection Agency. AP-42. Section 1.10 – Residential Woodstoves.

4. U.S. Environmental Protection Agency. AP-42. Section 9.9.6 – Bakeries.

5. Radian Corporation. Estimation of Emissions from Charcoal Lighter Fluid and Review of Alternatives. January 1990. Prepared for U.S. Environmental Protection Agency. PB90-186313.

6. U.S. Environmental Protection Agency. Non-road Engine and Vehicle Emission Study Report. November 1991. Office of Mobile Sources. EPA-21A-2001.

7. U.S. Environmental Protection Agency. Locating and Estimating Air Emissions of Benzene. Office of Air Quality Planning and Standards. EPA-454/R-98-011.

8. U.S. Environmental Protection Agency. Locating and Estimating Air Emissions of Toluene. Office of Air Quality Planning and Standards. EPA-454/R-93-048.

9. U.S. Environmental Protection Agency. Locating and Estimating Air Emissions of Xylene. Office of Air Quality Planning and Standards. EPA-454/R—93-047.

10. Rogge, WF, et.al. Sources of Fine Organic Aerosol. 1 – Charbroilers and Meat Cooking Operations. 1991. Environmental Science and Technology, Volume 25, Number 6, 1112-1125.

11. U.S. Environmental Protection Agency. Northeast Cooperative Woodstove Study. November 1987. Office of Research and Development. EPA/600/7-87-026a.

12. U.S. Environmental Protection Agency. Alternative Control Technology Document for Bakery Oven Emissions. December 1992. Office of Air Quality Planning and Standards. EPA/453/R-92-017.

Table 1. Emission Factor Table

Pollutant	Hot Mix Asphalt			Residential Fireplaces			Residential Woodstoves			Bakeries			Barbeque Grills			Lawn Mowers			Auto Refueling			Fast-food Restuarants			HAP	VOC	PAH
	Emiss Factor	Units	Ref #	Emiss Factor	Units	Ref #	Emiss Factor	Units	Ref #	Emiss Factor	Units	Ref #	Emiss Factor	Units	Ref #	Emiss Factor	Units	Ref #	Emiss Factor	Units	Ref #	Emiss Factor	Units	Ref #			
PM*	0.33	lb/ton	1													7.7	lb/hp.hr	6									
PM10				34.6	lb/ton	2	19.6	lb/ton	3																		
CO	0.14	lb/ton	1	252.6	lb/ton	2	140.8	lb/ton	3																		
CO2	37	lb/ton	1	3400	lb/ton	2	ND																				
NOX	0.058	lb/ton	1	2.6	lb/ton	2	ND																				
N2O				0.3	lb/ton	2																					
SO2	0.011	lb/ton	1																								
SOX				0.4	lb/ton	2	0.4	lb/ton	3																		
TOC	0.044	lb/ton	1										0.0605	lb/min	5	437	lb/hp.hr	6				2,405	mg/kg	10		X	
TNMOC							12	lb/ton	3																	X	
CH4	0.012	lb/ton	1				16	lb/ton	3																		
VOC	0.032	lb/ton	1	229	lb/ton	2				6.9	lb/ton	4														X	
POM				1.60E-02	lb/ton	2																				X	
Ethane							1.47	lb/ton	3																		
Ethylene							4.49	lb/ton	3																	X	
Acetylene							1.124	lb/ton	3																	X	
Propane							0.358	lb/ton	3																	X	
Propene							1.244	lb/ton	3																	X	
i-Butane							0.028	lb/ton	3																	X	
n-Butane							0.056	lb/ton	3																	X	
Butenes							1.192	lb/ton	3																	X	
Pentenes							0.616	lb/ton	3																	X	
Aldehydes				2.4	lb/ton	2																				X	
Acetaldehyde																									X	X	
Benzene	5.10E-04	lb/ton	1				1.938	lb/ton	3										0.105	lb/1000 gal	7				X	X	
Ethylbenzene	2.40E-04	lb/ton	1																						X	X	
Formaldehyde	2.50E-03	lb/ton	1																						X	X	
Furan							0.342	lb/ton	3																	X	
Furfural							0.486	lb/ton	3																	X	
Methyl Chloroform	4.80E-05	lb/ton	1				0.29	lb/ton	3																X	X	
2-Methylfuran							0.656	lb/ton	3													16.1	mg/kg	10		X	
2,5-Dimethyl Furan							0.162	lb/ton	3																	X	
Quinone																									X	X	
Toluene	1.5E-04	lb/ton	1				0.73	lb/ton	3										139.9	mg/l	8				X	X	
Xylene	2.0E-04	lb/ton	1																5.5	mg/l	9				X	X	
o-Xylene							0.202	lb/ton	3																X	X	
Benzaldehyde																										X	
Butyraldehyde/Isobutyraldehyde																										X	
Crotonaldehyde																										X	
Hexane	9.20E-04	lb/ton	1																							X	
2-Methylnapthalene	7.40E-05	lb/ton	1																							X	X
Acenaphthene	1.40E-06	lb/ton	1				0.01	lb/ton	3																	X	X
Acenaphthylene	8.60E-06	lb/ton	1				0.032	lb/ton	3																	X	X
Anthracene	2.20E-07	lb/ton	1				0.009	lb/ton	3																	X	X
Benzo(a)anthracene	2.10E-07	lb/ton	1																			0.29	mg/kg	10		X	X
Benzo(b)fluoranthene	4.10E-08	lb/ton	1				0.004	lb/ton	3													0.21	mg/kg	10		X	X
Benzo(g,h,i)Fluoranthene							0.028	lb/ton	3																	X	X
Benzo(g,h,i)perylene	1.10E-07	lb/ton	1				0.02	lb/ton	3																	X	X
Benzo(k)fluoranthene	4.10E-08	lb/ton	1																							X	X
Benzo(a)Pyrene	9.80E-09	lb/ton	1				0.006	lb/ton	3													0.19	mg/kg	10		X	X
Benzo(e)Pyrene							0.002	lb/ton	3													0.19	mg/kg	10		X	X
Biphenyl							0.022	lb/ton	3																X	X	X

Table 1. Emission Factor Table

Pollutant	Hot Mix Asphalt			Residential Fireplaces			Residential Woodstoves			Bakeries			Barbeque Grills			Lawn Mowers			Auto Refueling			Fast-food Restuarants					
	Emiss Factor	Units	Ref #	Emiss Factor	Units	Ref #	Emiss Factor	Units	Ref #	Emiss Factor	Units	Ref #	Emiss Factor	Units	Ref #	Emiss Factor	Units	Ref #	Emiss Factor	Units	Ref #	Emiss Factor	Units	Ref #	HAP	VOC	PAH
Chrysene	1.80E-07	lb/ton	1				0.01	lb/ton	3																	X	X
Dibenzo(a,h)anthracene	9.50E-11	lb/ton	1				0.004	lb/ton	3																	X	X
7,12-Dimethylbenz(a)Anthracene							0.004	lb/ton	3																	X	X
Fluoranthene	6.10E-07	lb/ton	1				0.008	lb/ton	3													0.35	mg/kg	10		X	X
Fluorene	3.80E-06	lb/ton	1				0.014	lb/ton	3																	X	X
Indendo(1,2,3-cd)pyrene	3.00E-10	lb/ton	1				0.02	lb/ton	3																	X	X
9-Methylanthracene							0.004	lb/ton	3																	X	X
12-Methylbenz(a)Anthracene							0.002	lb/ton	3																	X	X
1-Methylphenanthrene							0.03	lb/ton	3																	X	X
Naphthalene	9.00E-05	lb/ton	1				0.144	lb/ton	3																X	X	X
Perylene							0.002	lb/ton	3																	X	X
Phenanthrene	7.60E-06	lb/ton	1				0.118	lb/ton	3																	X	X
Pyrene	5.40E-07	lb/ton	1				0.008	lb/ton	3													0.74	mg/kg	10		X	X
Arsenic	5.60E-07	lb/ton	1																								
Barium	5.80E-06	lb/ton	1																								
Beryllium																											
Cadmium	4.10E-07	lb/ton	1				2.0E-05	lb/ton	3																		
Chromium	5.50E-06	lb/ton	1																								
Hexavalent chromium	4.50E-07	lb/ton	1																								
Copper	3.10E-06	lb/ton	1																								
Lead	1.50E-05	lb/ton	1																								
Manganese	7.70E-06	lb/ton	1				1.4E-04	lb/ton	3																		
Mercury	2.60E-06	lb/ton	1																								
Nickel	6.30E-05	lb/ton	1				2.0E-05	lb/ton	3																		
Selenium	3.50E-07	lb/ton	1																								
Zinc	6.10E-05	lb/ton	1																								
Hydrogen sulfide																											

Table 2. Hot Mix Asphalt Emission Estimates

Pollutant	Emission factor	Units	Ref #	Emissions from a typical plant (tons/yr)
PM[b]	0.033	lb/ton	1	3.37
CO[b]	0.14	lb/ton	1	14.1
CO2	32	lb/ton	1	3200
NOX	0.058	lb/ton	1	5.8
SO2	0.011	lb/ton	1	1.1
TOC[a]	0.044	lb/ton	1	4.93
CH4	0.012	lb/ton	1	1.2
VOC	0.032	lb/ton	1	3.2
Isooctane	4.00E-05	lb/ton	1	0.004
Benzene	5.10E-04	lb/ton	1	0.051
Ethylbenzene	2.40E-04	lb/ton	1	0.024
Formaldehyde	2.50E-03	lb/ton	1	0.250
Toluene	1.50E-04	lb/ton	1	0.015
Xylene	2.00E-04	lb/ton	1	0.020
2-Methylnapthalene	7.40E-05	lb/ton	1	0.0074
Acenaphthene	1.40E-06	lb/ton	1	1.40E-04
Acenaphthylene	8.60E-06	lb/ton	1	8.60E-04
Anthracene	2.20E-07	lb/ton	1	2.20E-05
Benzo(a)anthracene	2.10E-07	lb/ton	1	2.10E-05
Benzo(a)pyrene	9.80E-07	lb/ton	1	9.80E-07
Benzo(b)fluoranthene	1.00E-07	lb/ton	1	1.00E-05
Benzo(g,h,i)perylene	1.10E-07	lb/ton	1	1.10E-05
Benzo(k)fluoranthene	4.10E-08	lb/ton	1	4.10E-06
Chrysene	1.80E-07	lb/ton	1	1.80E-05
Fluoranthene	6.10E-07	lb/ton	1	6.10E-05
Fluorene	3.80E-06	lb/ton	1	3.80E-04
Indendo(1,2,3-cd)pyrene	7.00E-09	lb/ton	1	7.00E-07
Naphthalene	9.00E-05	lb/ton	1	9.00E-03
Phenanthrene	7.60E-06	lb/ton	1	7.60E-04
Pyrene	5.40E-07	lb/ton	1	5.40E-04
TOTAL PAHs	1.87E-04			1.87E-02
Arsenic	5.60E-07	lb/ton	1	5.60E-05
Barium	5.80E-06	lb/ton	1	5.80E-04
Cadmium	4.10E-07	lb/ton	1	4.10E-05
Chromium	5.50E-06	lb/ton	1	5.50E-04
Hexavalent chromium	4.50E-07	lb/ton	1	4.50E-05
Copper	3.10E-06	lb/ton	1	3.10E-04
Lead	1.50E-05	lb/ton	1	1.50E-03
Manganese	7.70E-06	lb/ton	1	7.70E-04
Mercury	2.60E-06	lb/ton	1	2.60E-04
Nickel	6.30E-05	lb/ton	1	6.30E-03
Selenium	3.50E-07	lb/ton	1	3.50E-05
Zinc	6.10E-05	lb/ton	1	6.10E-03

[a] Emissions from rotary drum dryer and load-out, silo filling, and post load out operations.
[b] Emissions from rotary drum dryer and load-out and silo filling operations.

Table 2. Hot Mix Asphalt Emission Estimates

Calculations & Assumptions:

Post load out TOC emissions = 0.0011 lb/ton of asphalt loaded 1.10E+02 lb/yr
Post load out TOC emissions = 5.50E-02 tons/yr
Load-out and silo filling operation emissions
PMtot EF (lb/ton)=.000181+0.00214(-V)e$^{[(0.0251)(T+460)-20.43]}$

V = asphalt volatility, default value of -0.5
T = Asphalt temp in F, default temp of 325F

PMtot EF (lb/ton) = 0.000181+0.00214(-(-0.5))e$^{((0.0251)(325+460)-20.43))}$
PMtot EF (lb/ton) = 0.000181+0.00214*0.5*0.4836
PMtot EF (lb/ton) = 0.000698
PMtot emissions from load-out and silo filling operations (tons/yr) = EF * 100,000 tons/yr *1 ton/2000 lb
0.0349

TOC EF (lb/ton)= 0.0172(-V)e$^{[(0.0251)(T+460)-20.43]}$
TOC EF (lb/ton) = 0.0172*0.5*0.4836
TOC EF (lb/ton) = 0.004159
TOC emissions from load-out and silo filling operations (tons/yr) = EF * 100,000 tons/yr *1 ton/2000 lb
TOC emissions from load-out and silo filling operations (tons/yr) = 0.208

CO EF (lb/ton) = 0.00558(-V)e$^{[0.0251)(T+460)-20.43]}$
CO EF (lb/ton) = 0.00558*0.5*0.4836
CO EF (lb/ton) = 0.001349
CO emissions from load-out and silo filling operations (tons/yr) = EF * 100,000 tons/yr *1 ton/2000 lb
CO emissions from load-out and silo filling operations (tons/yr) = 0.0675

Notes:

- Emissions were calculated for a continuous drum mix asphalt plant with 200,000 tons per year production.
- Emissions were based on #2 fuel oil used for dryers.
- For HAP and PAH emissions it was assumed that the dryer had a fabric filter.
- No emissions for hot oil heaters were included.
- No lead emissions from a waste oil-fired dryer were included.
- No uncontrolled fugitive PM emissions from the following sources were included: crushed stone processing, paved roads, unpaved roads, heavy construction operations and aggregate handling and storage piles.
- No emissions from asphalt storage tanks were included.

Table 3. Residential Fireplace Emission Estimates

Pollutant	Emission Factor	Units	Ref #	Emissions per household (ton/yr)	Emissions for 13 households (ton/yr)
PM10	34.6	lb/ton	2	0.0373	0.0485
CO	252.6	lb/ton	2	0.2726	3.544
CO2	3400	lb/ton	2	3.6688	47.70
NOX	2.6	lb/ton	2	0.0028	0.0365
N2O	0.3	lb/ton	2	0.0003	0.0042
SOX	0.4	lb/ton	2	0.0004	0.0056
VOC	229	lb/ton	2	0.2471	3.212
POM	1.60E-02	lb/ton	2	1.73E-05	0.0002
Aldehydes	2.4	lb/ton	2	0.0026	0.0337

Calculations & Assumptions

Throughput of an average fireplace: Assume that the same amount of wood is burned in the average woodstove as in the average fireplace annually.

Reference 11: P.G. Burnet, Northeast Cooperative Woodstove Study. Volume 1, EPA/600/7-87-026a, U.S. Environmental Protection Agency, Cincinnati, OH, November 1987. Equation from Reference 11 is as follows:

1. Calculate an average wood use by calculating an average of the mean wood use values for all stove types using scale weighing and woodpile measurements.

   Aver wood use per household = (0.64+0.85+0.53+0.91+0.67+0.85+0.46+0.89)/8
   Aver wood use per household = 0.725 dry kg of wood/ heating degree days (HDD)

2. Convert wood use from dry kg/1000 HDD to tons dry wood use/year
   (a) Convert from kg to tons dry kg/1000

   0.725 HDD X 2.205 lb/kg X 1ton/2000 lb
   7.99E-04 dry ton wood/ heating degree days (HDD)

   (b) Convert from 1000 HDD to year
   Assume that the Vermont and upstate New York region has three times as many HDD as the rest of the country. The reference reported 8,000 to 9,000 HDD/yr. Therefore, assume that there are 2,700 HDD/year.

   7.99E-04 dry ton wood X 2,700 HDD

   = 2.16 dry ton wood/yr

Table 4. Residential Woodstove Emission Estimates

Pollutant	Emiss Factor	Units	Ref #	Emissions per household per year (tons/yr)	Emissions for 382 households (tons/yr)
PM10	19.6	lb/ton	1	2.11E-02	8.08E+00
CO	140.8	lb/ton	1	1.52E-01	5.80E+01
SOX	0.4	lb/ton	1	4.32E-04	1.65E-01
TNMOC	12	lb/ton	1	1.29E-02	4.95E+00
CH4	16	lb/ton	1	1.73E-02	6.59E+00
Ethane	1.47	lb/ton	1	1.59E-03	6.06E-01
Ethylene	4.49	lb/ton	1	4.84E-03	1.85E+00
Acetylene	1.124	lb/ton	1	1.21E-03	4.63E-01
Propane	0.358	lb/ton	1	3.86E-04	1.48E-01
Propene	1.244	lb/ton	1	1.34E-03	5.13E-01
i-Butane	0.028	lb/ton	1	3.02E-05	1.15E-02
n-Butane	0.056	lb/ton	1	6.04E-05	2.31E-02
Butenes	1.192	lb/ton	1	1.29E-03	4.91E-01
Pentenes	0.616	lb/ton	1	6.65E-04	2.54E-01
Benzene	1.938	lb/ton	1	2.09E-03	7.99E-01
Furan	0.342	lb/ton	1	3.69E-04	1.41E-01
Furfural	0.486	lb/ton	1	5.24E-04	2.00E-01
MethylEthylKetone	0.29	lb/ton	1	3.13E-04	1.20E-01
2-Methylfuran	0.656	lb/ton	1	7.08E-04	2.7E-01
2,5-Dimethyl Furan	0.162	lb/ton	1	1.75E-04	6.68E-02
Toluene	0.73	lb/ton	1	7.88E-04	3.01E-01
o-Xylene	0.202	lb/ton	1	2.18E-04	8.33E-02
Acenaphthene	0.01	lb/ton	1	1.08E-05	4.12E-03
Acenaphthylene	0.032	lb/ton	1	3.45E-05	1.32E-02
Anthracene	0.009	lb/ton	1	9.71E-06	3.71E-03
Benzo(b)fluoranthene	0.004	lb/ton	1	4.32E-06	1.65E-03
Benzo(g,h,I)Fluoranthene	0.028	lb/ton	1	3.02E-05	1.15E-02
Benzo(g,h,I)perylene	0.02	lb/ton	1	2.16E-05	8.24E-03
Benzo(a)Pyrene	0.006	lb/ton	1	6.47E-06	2.47E-03
Benzo(e)Pyrene	0.002	lb/ton	1	2.16E-06	8.24E-04
Biphenyl	0.022	lb/ton	1	2.37E-05	9.07E-03
Chrysene	0.01	lb/ton	1	1.08E-05	4.12E-03
Dibenzo(a,h)anthracene	0.004	lb/ton	1	4.32E-06	1.65E-03
7,12-Dimethylbenz(a)Anthracene	0.004	lb/ton	1	4.32E-06	1.65E-03
Fluoranthene	0.008	lb/ton	1	8.63E-06	3.30E-03
Fluorene	0.014	lb/ton	1	1.51E-05	5.77E-03
Indendo(1,2,3-cd)pyrene	0.02	lb/ton	1	2.16E-05	8.24E-03
9-Methylanthracene	0.004	lb/ton	1	4.32E-06	1.65E-03
12-Methylbenz(a)Anthracene	0.002	lb/ton	1	2.16E-06	8.24E-04
1-Methylphenanthrene	0.03	lb/ton	1	3.24E-05	1.24E-02
Naphthalene	0.144	lb/ton	1	1.55E-04	5.94E-02
Perylene	0.002	lb/ton	1	2.16E-06	8.24E-04
Phenanthrene	0.118	lb/ton	1	1.27E-04	4.86E-02
Pyrene	0.008	lb/ton	1	8.63E-06	3.30E-03
Total PAHs				5.41E-04	2.07E-01
Cadmium	2.0E-05	lb/ton	1	2.16E-08	8.24E-06
Manganese	1.4E-04	lb/ton	1	1.51E-07	5.77E-05
Nickel	2.0E-05	lb/ton	1	2.16E-08	8.24E-06

Table 4. Residential Woodstove Emission Estimates

Calculations &Assumptions:

Noncatalytic woodstove type assumed for criteria pollutants, PAH's and metals. Conventional stove type assumed for organic pollutants.

Assume the same wood use as was calculated for the fireplace calculations, which is 2.16 dry tons of wood/yr.

Table 5. Bakery Emission Estimates

Pollutant	Emission Factor	Units	Ref #	Emissions ton/yr) (from equation)
VOC	6.9	lb/ton	4	60

Calculations & Assumptions:

Reference for values in equation and bread production: Alternative Control Technology Document for Bakery Oven Emissions, EPA 453/R-92-017, December 1992.

From the model ovens listed in the ACT, the one with medium-sized production and the largest emission factor was chosen, that is, model oven number 23. In addition to listing values for the variables in the emission factor equation, the ACT listed the emission factor and annual VOC emissions. These numbers were used.

AP-42 Equation:

VOC= 0.95Yi+0.195ti-0.51S-0.86ts+1.90

lb VOC per ton baked bread; Y i= initial baker's % of yeast; t i= total yeast action time in hours; S = final (spike) baker's % of yeast; ts = spiking time in hours

The variables for model oven no. 23 are: oven size=6X10^6 BTU/hr, Bread production = 17,308 tons /yr, Y=4.25, S=0, ti=5.15, ts=0, VOC emission factor (lbs/ton) = 6.9 and VOC Emissions (tons/yr) = 60

Table 6. Barbeque Emission Estimates

Pollutant	Emission Factor	Units	Ref #	Emissions per Household per year (tons/yr)	Emissions for Neighborhood of 271 Households (tons/yr)
TOC	0.0605	lb/min	5	0.01815	4.9

Calculations & Assumptions:

Cooking time (min) on barbeque grill	30
Number of times per year using grill	20

Single household emissions

0.0605 lb/min * 30 min/event * 20 events/yr

= 36 lb/yr

= 0.01815 tons/yr

Table 7. Lawn Mower Emission Estimates

Pollutant	Emission Factor	Units	Ref #	Emissions per Household per year (tons/yr)	Emissions for Neighborhood of 171 Households (tons/yr)
TOC	437	g/hp-hr	6	0.02888	4.938
PM	7.7	g/hp-hr	6	0.00051	0.087
Aldehydes	2	g/hp-hr	6	0.00013	0.023

Calculations & Assumptions:

Ave horsepower rating @ 30% load 1.2
Ave hours per year of operation 50

Calculation for TOC

(437 g/hp-hr * 1.2 hp* 50 hrs/yr) /(454 g/lb *2000 lb/ton)

= 0.02888 tons/yr

Table 8. Auto Refueling Emission Estimates

Pollutant	Emission Factor	Units	Ref #	Annual Emissions (tons/yr)
Benzene	0.105	lb/1000 gal	7	0.032
Toluene	139.9	mg/l	8	0.350
Xylene	5.5	mg/l	9	0.014
Total "VOC"				0.393

Calculations & Assumptions:

Throughput: Locating and Estimating document reported that the average filling station's throughput is 50,000 gallons per month.

Benzene emissions = 0.105 lb/1000gal *50 (1000gal/mo) * 12 mo/yr * 1 ton/2000 lb

= 0.0315 tons/yr

Toluene emissions = 139.9 mg/l * 3.7854 l/gal * 50000 gal/mo * 12 mo/yr * 1 g/1000mg * 1 lb/453.593g * 1 ton/2000lb

= 0.350 tons/yr

Xylene emissions = 5.5 mg/l * 3.7854 l/gal * 50000 gal/mo * 12 mo/yr * 1 g/1000mg * 1 lb/453.593g * 1 ton/2000lb

= 0.0138 tons/yr

Table 9. Fast-Food Restaurant Emission Estimates

Pollutant	Emission Factor	Units	Ref #	Emissions (tons/yr)
TOC	2,405	mg/kg	10	0.18
2-Methylfuran	16.1	mg/kg	10	1.2E-03
Benzo(a)anthracene	0.29	mg/kg	10	2.1E-05
Benzo(b)fluoranthene	0.21	mg/kg	10	1.5E-05
Benzo(a)Pyrene	0.19	mg/kg	10	1.4E-05
Benzo(e)Pyrene	0.19	mg/kg	10	1.4E-05
Fluoranthene	0.35	mg/kg	10	2.6E-05
Pyrene	0.74	mg/kg	10	5.4E-05
Total PAHs				1.4E-04

Calculations & Assumptions:

To calculate throughput:

Called Walker Holdings Group on 9/11/00. They own 8 Wendy's restaurants in the NC/southern VA area.
Mr. Bert Walker reported that only data for their drive-thru sales were readily available.
Mr. Walker reported that the average (for 8 Wendy's) drive thru activity was 2,821 cars per week.
He added that the average check per car was $4.12.

Assumptions:
The same amount of sales occurred on foot (in the restaurant) as by the drive-thru.
The average sale consisted of one burger (plus fries and drink and other side dishes)
The average burger weighed 1/2 pound.
Throughput calculation:
Weekly number of sales = 2821*2 = 5642
Number of "half-pounders" sold = 5642
Weekly number of pounds of hamburger cooked = 5642/2 2821 lb/week
Annual mass of hamburger cooked at the average fast-food restaurant = weekly mass * 52
2821 lb/week * 52 weeks/yr
146692 lbs of hamburger cooked/yr

To calculate annual emissions:
TOC Emissions:
TOC Emissions (tons/yr) =
2405 mg/kg * 0.4536 kg/lb * 146692 lb/yr * 1 g/1000 mg * 1 b/453.593g *1 ton/2000lb
TOC Emissions (tons/yr) = 0.1764

Table 10. Annual Emissions (ton per year) Comparison Between Asphalt Plants and Selected Sources

Quantity	Source Category	TOC	VOC	PM	Toluene	Benzene	Total PAHs/POMs	Xylene
	Typical Asphalt Plant	4.9	3.2	3.4	0.015	0.051	0.019	0.02
13	Residential Fireplaces		3.2					
90	Residential Fireplaces			3.4				
1,100	Residential Fireplaces						0.019	
382	Residential Woodstoves	4.9						
160	Residential Woodstoves			3.4				
19	Residential Woodstoves				0.015			
25	Residential Woodstoves					0.052		
35	Residential Woodstoves						0.019	
1	Residential Woodstove							0.007
1	Bakery		60					
271	Barbecue Grills	4.9						
171	Household Lawn Mowers	4.9						
6,600	Lawn Mowers			3.4				
12	Gasoline Filling Stations	4.7						
1	Gasoline Filling Station				0.35	0.032		0.014
1.5	Gasoline Filling Stations							0.02
27	Fast-food Restaurants	4.9						
13	Fast-food Restaurants						0.019	