

FINAL

**Emissions Comparison:  
Continuous Drum Asphalt  
Plant and Selected Source  
Categories**

September 2001

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

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.<sup>11</sup> 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.<sup>12</sup>

### **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 negligible 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		Barbecue Grills		Lawn Mowers		Auto Refueling		Fast-food Restaurants		HAP	VOC	PAH
	Emiss Factor	Units	Emiss Factor	Units	Emiss Factor	Units	Emiss Factor	Units	Emiss Factor	Units	Emiss Factor	Units	Emiss Factor	Units	Emiss Factor	Units			
PM <sub>10</sub>	0.33	lb/ton	34.6	lb/ton	19.6	lb/ton					7.7	lb/hp.hr							
CO	0.14	lb/ton	252.6	lb/ton	140.8	lb/ton													
CO <sub>2</sub>	37	lb/ton	3400	lb/ton	ND														
NO <sub>x</sub>	0.058	lb/ton	2.6	lb/ton	ND														
N <sub>2</sub> O			0.3	lb/ton															
SO <sub>2</sub>	0.011	lb/ton																	
SO <sub>x</sub>	0.044	lb/ton	0.4	lb/ton	0.4	lb/ton													
TOC																			
TN/MOC					12	lb/ton													
CH <sub>4</sub>	0.012	lb/ton			16	lb/ton													
VOC	0.032	lb/ton	229	lb/ton															
POM			1.60E-02	lb/ton				6.9	lb/ton	0.0605	lb/min	437	lb/hp.hr	0.105	lb/100 gal	2.405	mg/kg	10	
Ethane					1.47	lb/ton													
Ethylene					4.49	lb/ton													
Acetylene					1.124	lb/ton													
Propane					0.358	lb/ton													
i-Butane					1.244	lb/ton													
n-Butane					0.028	lb/ton													
Butenes					0.056	lb/ton													
Pentenes					1.192	lb/ton													
Aldehydes					0.616	lb/ton													
Acetaldehyde			2.4	lb/ton															
Benzene	5.10E-04	lb/ton			1.938	lb/ton													
Ethylbenzene	2.40E-04	lb/ton																	
Formaldehyde	2.50E-03	lb/ton																	
Furan					0.342	lb/ton													
Furfural					0.486	lb/ton													
Methyl Chloroform	4.80E-05	lb/ton			0.29	lb/ton													
2-Methylfuran					0.656	lb/ton													
2,5-Dimethyl Furan					0.162	lb/ton													
Quinone																			
Toluene	1.5E-04	lb/ton			0.73	lb/ton								139.9	mg/l				
Xylene	2.0E-04	lb/ton												5.5	mg/l				
o-Xylene					0.202	lb/ton													
Benzaldehyde																			
Butyraldehyde/iso																			
lraldehyde																			
Crotonaldehyde																			
Hexane	9.20E-04	lb/ton																	
2-Methylnaphthalene	7.40E-05	lb/ton																	
Acenaphthene	1.40E-06	lb/ton			0.01	lb/ton													
Acenaphthylene	8.60E-06	lb/ton			0.032	lb/ton													
Anthracene	2.20E-07	lb/ton			0.009	lb/ton													
Benzo(a)anthracene	2.10E-07	lb/ton			0.004	lb/ton													
Benzo(b)fluoranthene	4.10E-08	lb/ton			0.028	lb/ton													
Benzo(g,h,i)fluoranthene					0.02	lb/ton													
Benzo(k)fluoranthene	1.10E-07	lb/ton																	
Benzo(e)pyrene	4.10E-08	lb/ton																	
Benzo(a)pyrene	9.80E-09	lb/ton			0.006	lb/ton													
Benzo(b)pyrene					0.002	lb/ton													
Biphenyl					0.022	lb/ton													



**Table 2. Hot Mix Asphalt Emission Estimates**

Pollutant	Emission factor	Units	Ref #	Emissions from a typical plant (tons/yr)
PM <sup>b</sup>	0.033	lb/ton	1	3.37
CO <sup>b</sup>	0.14	lb/ton	1	14.1
CO <sub>2</sub>	32	lb/ton	1	3200
NOX	0.058	lb/ton	1	5.8
SO <sub>2</sub>	0.011	lb/ton	1	1.1
TOC <sup>a</sup>	0.044	lb/ton	1	4.93
CH <sub>4</sub>	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
<b>TOTAL PAHs</b>	<b>1.87E-04</b>			<b>1.87E-02</b>
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

<sup>a</sup> Emissions from rotary drum dryer and load-out, silo filling, and post load out operations.

<sup>b</sup> 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

PM<sub>tot</sub> EF (lb/ton) =  $0.000181 + 0.00214(-V)e^{[(0.0251)(T+460)-20.43]}$

V = asphalt volatility, default value of -0.5

T = Asphalt temp in F, default temp of 325F

PM<sub>tot</sub> EF (lb/ton) =  $0.000181 + 0.00214(-(-0.5))e^{[(0.0251)(325+460)-20.43]}$

PM<sub>tot</sub> EF (lb/ton) =  $0.000181 + 0.00214 * 0.5 * 0.4836$

PM<sub>tot</sub> EF (lb/ton) = 0.000698

PM<sub>tot</sub> 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.

$$\text{Aver wood use per household} = (0.64+0.85+0.53+0.91+0.67+0.85+0.46+0.89)/8$$

$$\text{Aver wood use per household} = 0.725 \text{ dry kg of wood/ heating degree days (HDD)}$$

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

$$0.725 \text{ HDD} \times 2.205 \text{ lb/kg} \times 1\text{ton}/2000 \text{ lb}$$

$$7.99\text{E-}04 \text{ dry ton wood/ heating degree days (HDD)}$$

- (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.

$$7.99\text{E-}04 \text{ dry ton wood} \times 2,700 \text{ HDD}$$

$$= 2.16 \text{ dry ton wood/yr}$$

**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
Pentenenes	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.