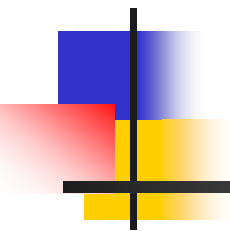


# Seattle Air Toxic Study 2002

## Temporal and Seasonal Distributions of PAH (polycyclic aromatic hydrocarbons) and Its Source Impact



Guangfeng Jiang<sup>1</sup>, Hal Westberg<sup>2</sup>, Rich Westberg<sup>1</sup>,  
John Williamson<sup>3</sup> and Carol Wieskopf<sup>4</sup>

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1. RJ Lee Group, Inc, Pasco, WA
2. Washington State University, Pullman, WA
3. Washington State Department of Ecology, Olympia, WA
4. Energy Northwest, Richland, WA



1 Lake forest park



3 Georgetown



2 Beacon Hill

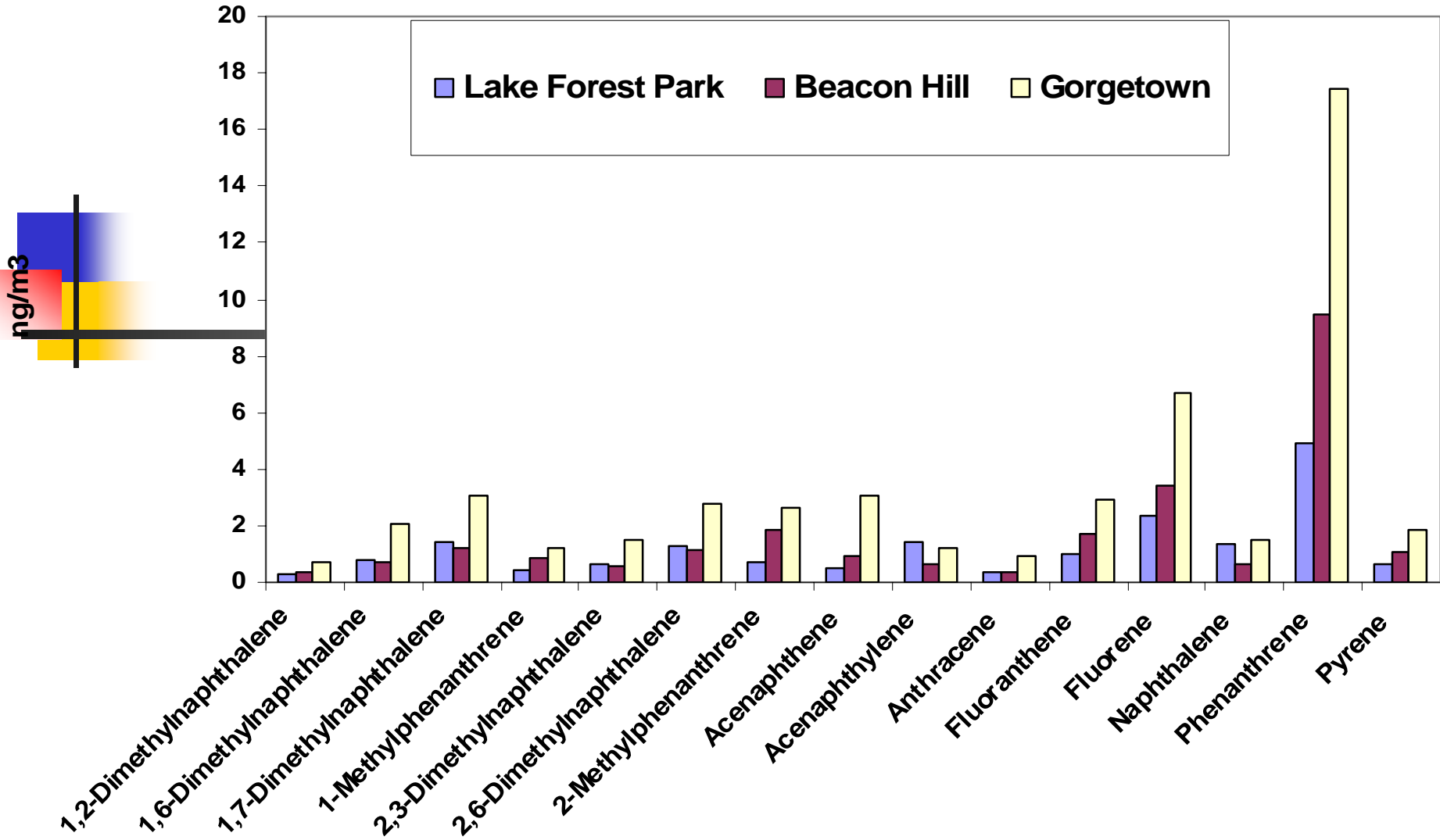


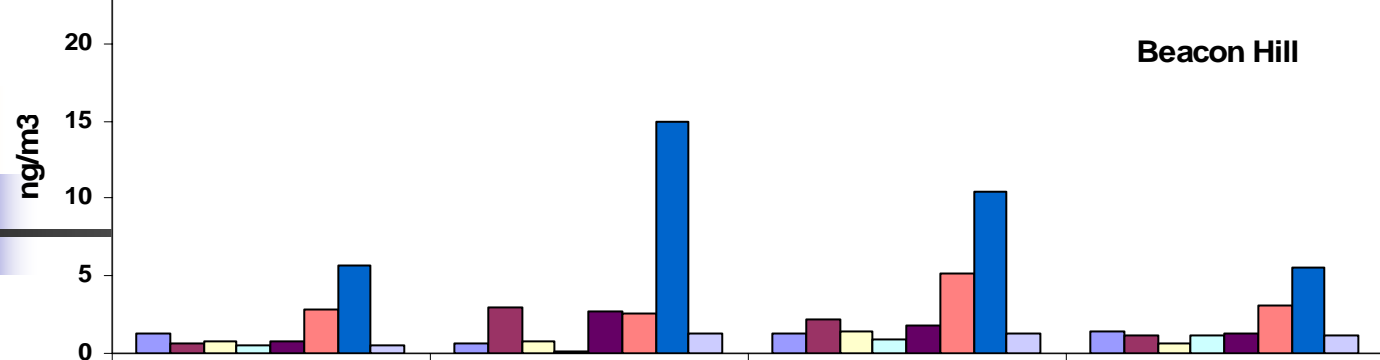
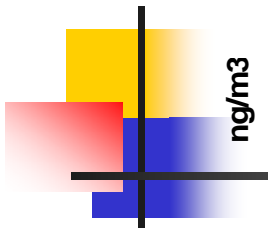
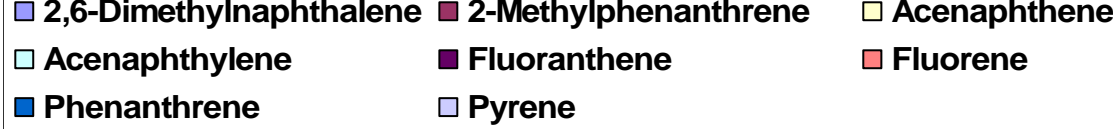
## **Analytical Method (TO-13)**

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- Hivol filter/puff plug collection
- Extraction of combined filter and puff
- GC/MS analysis

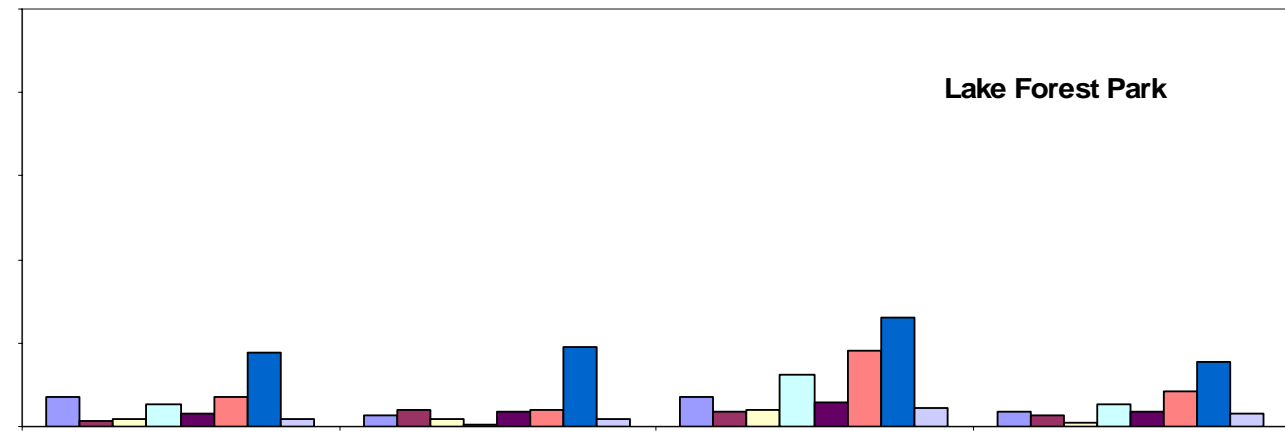
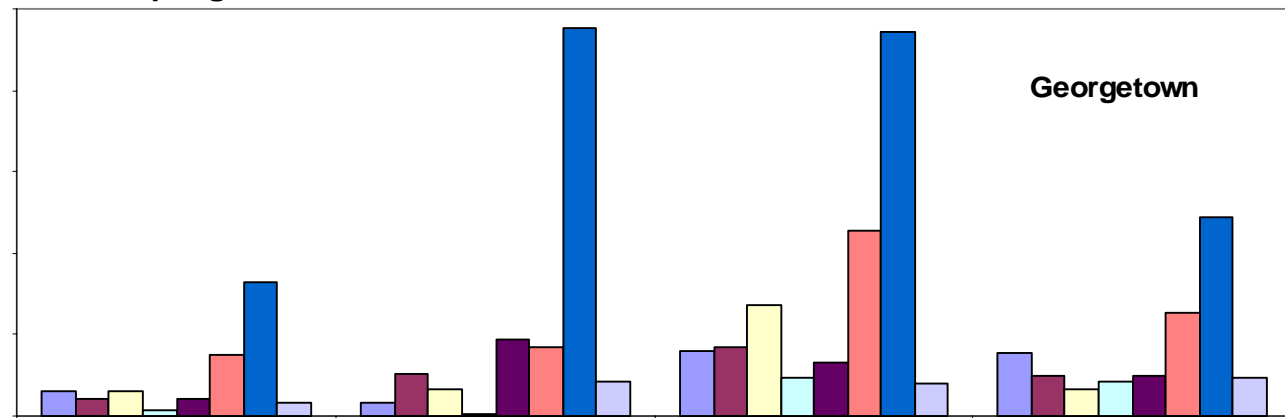
# Annual Mean PAH, March 2002 to February 2003





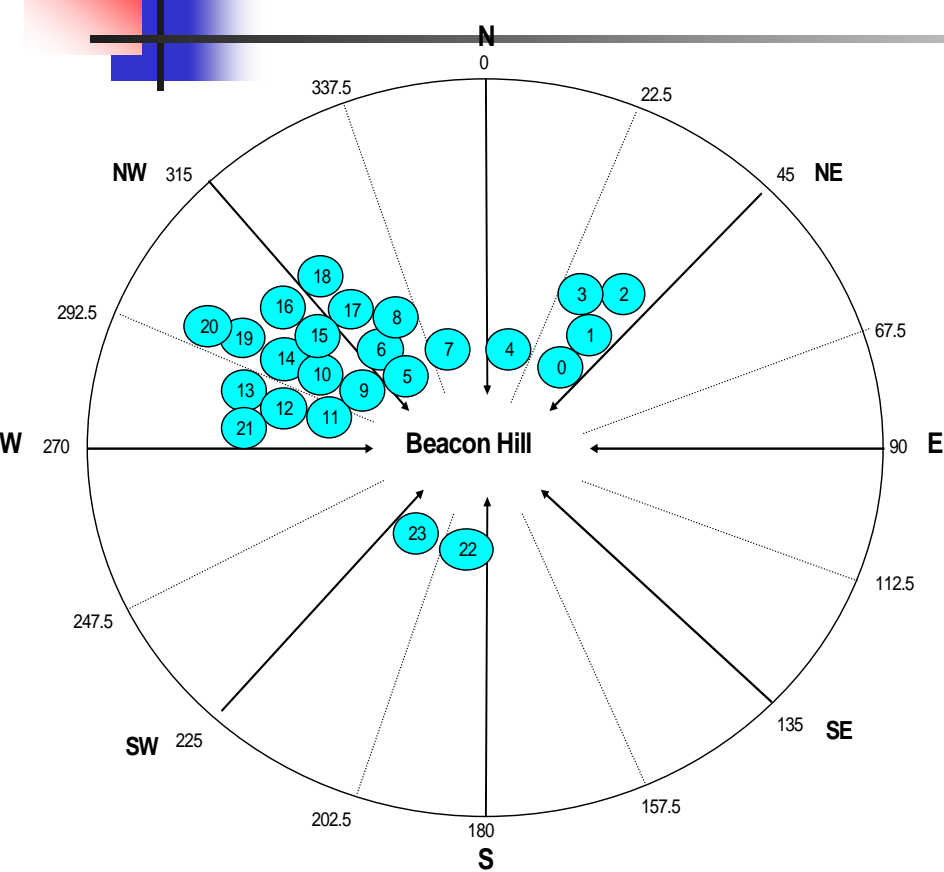
Seasonal →

↑  
Temporal  
↓

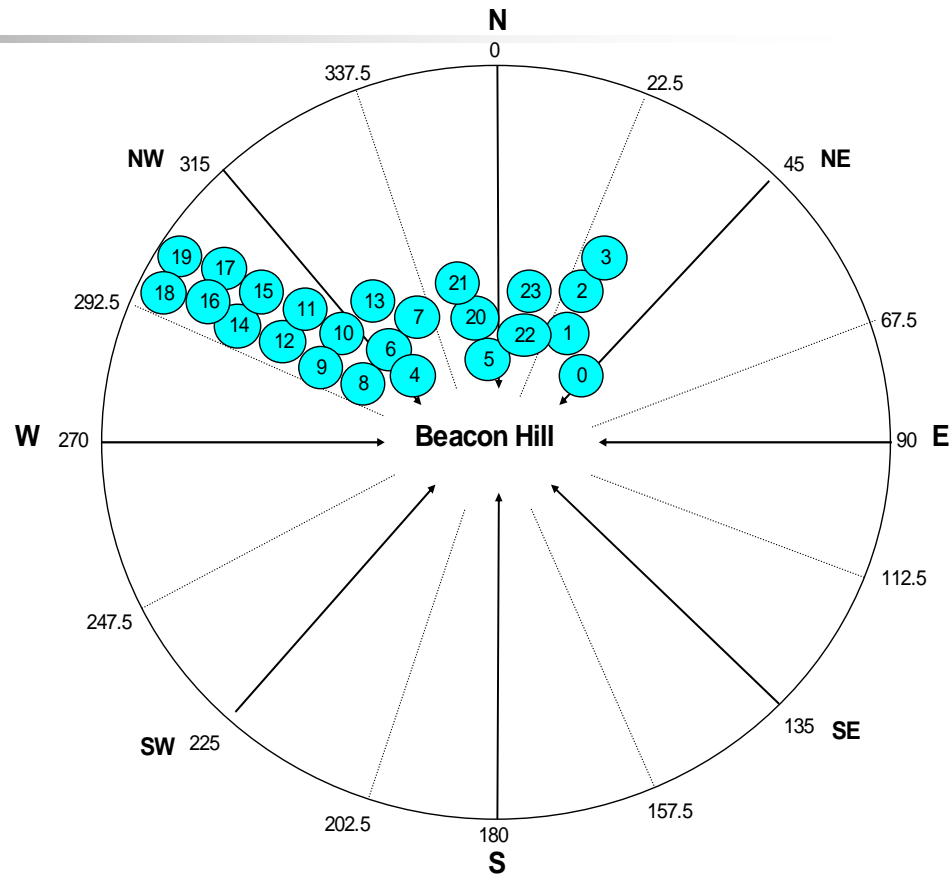


# PAH Levels and Wind Patterns

June 13, 2002, Phenanthrene  
daily average 44 ng/m<sup>3</sup>, top 1



June 25, 2002, Phenanthrene  
daily average 32 ng/m<sup>3</sup>, top 2





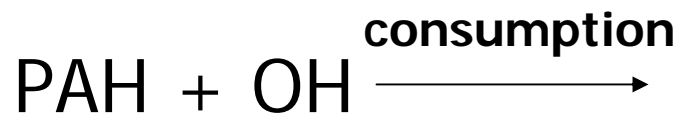
# PAH Seasonal Levels and Wind

	<b>Spring</b>	<b>Summer</b>	<b>Fall</b>	<b>Winter</b>
<b>Average hours of west and northwest wind</b>	<b>4.4</b>	<b>8.3</b>	<b>4.7</b>	<b>2.6</b>
<b>phenanthrene (ng/m<sup>3</sup>)</b>	<b>5.6</b>	<b>14.9</b>	<b>10.5</b>	<b>5.8</b>
<b>fluoranthene (ng/m<sup>3</sup>)</b>	<b>0.8</b>	<b>2.7</b>	<b>1.8</b>	<b>1.3</b>



# PAH Levels and Chemistry

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Temperature ↑

PAH ↓

Temperature ↑

$$\frac{\textit{PAH\_Reactive}}{\textit{PAH\_Less\_Reactive}}$$

↓



# PAH Reactivity

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Acenaphthylene  
Dimethylnaphthalenes

Acenaphthene  
Fluorene  
Naphthalene

Pyrene  
Fluoranthene  
Phenanthrene





# PAH Chemistry

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The levels of the two most reactive PAH species, acenaphthylene and dimethylnaphthalene, were extremely low in summer at all three sites of Seattle due to relatively high temperatures.



Total PAH of the southern cities (such as Atlanta) may be composed of less contents of reactive species than that of the northern cities (such as Seattle, Chicago).

# Correlations between PAH Species

## Beacon Hill, Whole Year

Y	X	R-square
Fluorene	Acenaphthene	<b>0.86</b>
	2,6-Dimethylnaphthalene	<b>0.70</b>
	Acenaphthylene	<b>0.59</b>

Phenanthrene	Fluoranthene	<b>0.87</b>
	2-Methylphenanthrene	<b>0.78</b>
	Pyrene	<b>0.67</b>

Y	X	R-square
Fluorene	Phenanthrene	0.22
	Fluoranthene	0.11
	2-Methylphenanthrene	0.15
	Pyrene	0.33
Phenanthrene	Fluorene	0.22
	Acenaphthene	0.26
	2,6-Dimethylnaphthalene	0.07
	Acenaphthylene	0.02

# Correlations between PAH Species

Under Temperature 276 to 286 K and 287 to 297 K

	Apyl	Aph	Flu	Phe	2Mphe	Flth	Pyr
26DNap	<b>0.71</b> 0.22	<b>0.78</b> 0.73	<b>0.71</b> 0.42	<b>0.55</b> 0.24	<b>0.50</b> 0.21	<b>0.38</b> 0.14	<b>0.46</b> 0.17
Apyl		<b>0.53</b> 0.19	<b>0.61</b> 0.19	<b>0.51</b> 0.00	<b>0.49</b> 0.00	<b>0.51</b> 0.00	<b>0.69</b> 0.01
Aph			<b>0.91</b> 0.51	<b>0.79</b> 0.36	<b>0.65</b> 0.16	<b>0.49</b> 0.29	<b>0.44</b> 0.22
Flu				<b>0.87</b> 0.67	<b>0.69</b> 0.54	<b>0.59</b> 0.49	<b>0.55</b> 0.44
Phe					<b>0.77</b> 0.71	<b>0.69</b> 0.92	<b>0.64</b> 0.84
2Mphe						<b>0.85</b> 0.52	<b>0.69</b> 0.60
Flth							<b>0.74</b> 0.81

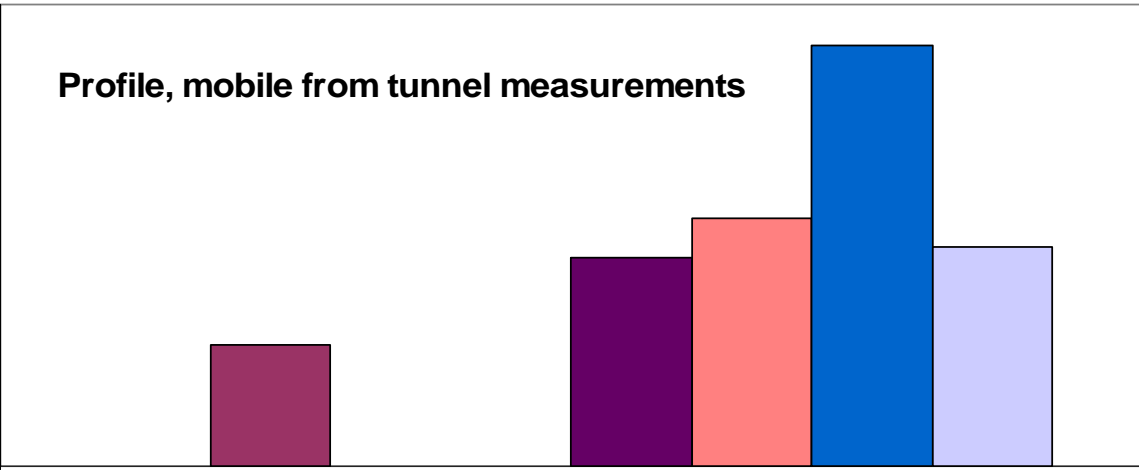
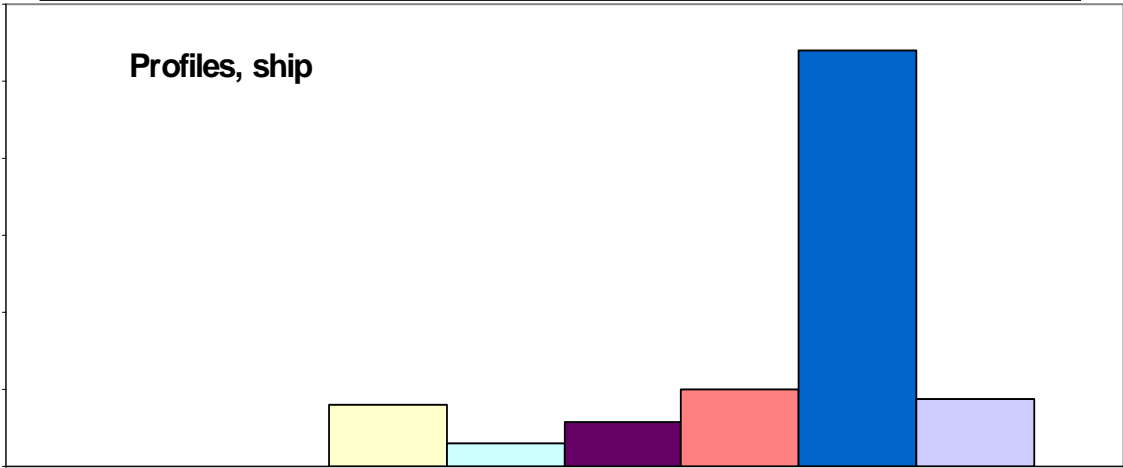
26DNap	2,6-Dimethylnaphthalene	Phe	Phenanthrene
Apyl	Acenaphthylene	2Mphe	2-Methylphenanthrene
Aph	Acenaphthene	Flth	Fluoranthene
Flu	Fluorene	Pyr	Pyrene

# Correlations between NOx and PAH at Beacon Hill

	<b>Apyl</b>	<b>26D</b>	<b>Aph</b>	<b>Flu</b>	<b>Phe</b>	<b>2Mphe</b>	<b>Flth</b>	<b>Pyr</b>
<b>whole year</b>	0.41	0.49	0.56	0.59	0.26	0.23	0.21	0.41
<b>276 K - 286 K</b>	0.28	0.23	0.32	0.29	0.38	0.63	0.55	0.48
<b>287 K - 297 K</b>	<b>0.76</b>	<b>0.78</b>	<b>0.78</b>	<b>0.87</b>	0.38	0.21	0.20	0.43

26DNap	2,6-Dimethylnaphthalene	Phe	Phenanthrene
Apyl	Acenaphthylene	2Mphe	2-Methylphenanthrene
Aph	Acenaphthene	Flth	Fluoranthene
Flu	Fluorene	Pyr	Pyrene

# Available PAH Profiles



# Ratios between PAH Species at Beacon Hill Sorted by Daily Average Temperature

		Phenanthrene/PAH						
		26D	Apyl	Aph	Flu	2Mphe	Flth	Pyr
<b>Kristensson 2004</b>					1.7	3.5	2.0	1.9
<b>Harrison 2003</b>			5.2	15.5	2.4	3.9	2.6	2.9
<b>Wingfords 2001</b>		7.5	22.4	24.1	3.7		3.3	2.8
<b>Cooper 2001 boat</b>		2.3	17.4	6.8	5.4		9.5	6.1
Date	MEAN T							
02/08/03	276	5.4	4.3	11.8	2.0	8.7	3.9	4.8
03/15/02	277	5.0	6.7	6.7	1.4	4.8	3.2	6.7
01/15/03	277	2.6	3.8	5.5	1.7	4.6	5.6	4.9
03/21/02	278	1.6	2.4	3.3	1.6	4.1	4.4	4.9
03/27/02	279	3.6	12.4	8.9	2.0	6.9	5.6	4.0
09/09/02	291	BDL	BDL	BDL	7.2	6.5	5.4	7.0
07/13/02	293	44.2	BDL	14.7	6.8	6.4	4.8	11.8
06/25/02	294	22.2	BDL	25.6	5.9	2.7	6.7	10.8
08/12/02	294	BDL	BDL	BDL	18.9	5.4	4.6	10.2
06/13/02	297	36.8	BDL	17.7	7.8	5.6	4.4	11.7

# Ratios between PAH Species of Top Five Annual Levels at Beacon Hill

	Phenanthrene/PAH								
	26D	Apyl	Aph	Flu	2Mphe	Flth	Pyr		
Kristensson 2004				1.7	3.5	2.0	1.9		
Harrison 2003		5.2	15.5	2.4	3.9	2.6	2.9		
Wingfords 2001	7.5	22.4	24.1	3.7		3.3	2.8		
Cooper 2001 boat	2.3	17.4	6.8	5.4		9.5	6.1		
Date	Total PAH (ng/m3)	Temp (K)	26D	Apyl	Aph	Flu	2Mphe	Flth	Pyr
10/17/02	116.8	286	2.9	5.8	2.5	1.0	5.4	8.3	8.5
06/13/02	80.6	297	36.8	BDL	17.7	7.8	5.6	4.4	11.7
06/25/02	68.9	294	22.2	BDL	25.6	5.9	2.7	6.7	10.8
10/23/02	67.9	283	5.6	8.7	3.9	1.5	4.8	6.2	9.4
11/04/02	51.0	279	11.1	5.3	13.0	1.7	7.5	6.8	5.2



# PAH Levels Reported in Other Cities

	Chesapeak Bay July 1997 conc (ng/m3)	Baltimore inner harbor July 1997 conc (ng/m3)	Galveston Bay Feb 1995 - Aug 1996 conc (ng/m3)
Fluorene	2.7	4.1	1.6
Phenanthrene	5.6	12.6	11.9
total PAH	21.0	41.5	51.8

<b>Seattle</b>	LFP annual mean (ng/m3)	BH annual mean (ng/m3)	GT annual mean (ng/m3)
Fluorene	2.3	3.4	6.4
Phenanthrene	5.0	9.5	17.4
total PAH	18.4	24.6	47.9



## Summary

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- Fifteen species of PAH were routinely detected and quantified at three sites of Seattle. Most of these species shared the same sources and mobile emissions were considered to be the major sources.
- PAH of Beacon Hill and Georgetown had the similar source impacts: automobile emissions and possible ship emissions from the west and northwest directions.
- PAH of Lake Forest Park may be impacted by both mobile emissions and wood smoke, particularly in the fall.
- Top levels of PAH could be resulted from either high levels of reactive species or less reactive species or both.