PERSONAL, INDOOR AND OUTDOOR MONITORING OF EXPOSURES TO POLYCYLIC AROMATIC HYDROCARBONS AMONG A COHORT OF PREGNANT WOMEN FROM KRAKOW, POLAND

K Peki[1*], R Whyatt[1], W Jedrychowski[3], D Camann[2], A Penar[3], U Bawle[1], J Adibi[1] and F Perera[1]

[1]Environmental Health Sciences Division, Mailman School of Public Health, Columbia University
[2]Southwest Research Institute, San Antonio, TX 78228
[3]Jagellionian University, Krakow, Poland.

ABSTRACT
Polycyclic aromatic hydrocarbons (PAH) are widespread pollutants produced by incomplete combustion. The city of Krakow in Poland is an industrialized area with high concentrations of PAH in the ambient air. As part of a prospective cohort study being conducted among pregnant women from Krakow, we have measured PAH levels in personal, indoor and outdoor air monitoring over 48-hours collected from 27 women during the 2nd trimester of pregnancy. The monitoring was conducted between January, 2001 and August, 2001. Results show high but variable exposures (ng/m^3): Benz(a)pyrene (0.24-36.79); Benz(a)anthracene(0.39-36.69); Benz(b)fluoranthene (0.42-32.64); benzo(k)fluoranthene (0.18-11.25); chrysene (0.34-29.72); dibenz(a,h)anthracene (0.17-9.41); indeno(1,2,3-cd)pyrene (0.55-50.20); pyrene (1.46-47.12). Outdoor PAH levels were higher than indoor levels. Personal levels were lower or similar to outdoor levels and higher than indoor levels. Indoor, outdoor and personal levels were all highly correlated ($r>0.93$). PAH levels were higher in the samples collected during the winter compared to the summer months. These findings show substantial PAH exposures among cohort women during pregnancy.

INDEX TERMS
Polycyclic aromatic hydrocarbons, Air monitoring, Pregnancy, Environmental exposure

INTRODUCTION
This study focuses on the magnitude of individual variation in exposure to polycyclic aromatic hydrocarbons (PAH) within a population of pregnant women in Krakow during the second trimester of pregnancy. PAH are widespread pollutants commonly found in ambient air, as well as workplace air, food and drinking water (Chuang et al., 1991; Lewtas, 1994; Aceves and Grimalt, 1993). The major sources of ambient PAH are incomplete combustion of gasoline and diesel fuels by transportation sources, and burning of coal and oil for industrial purposes and residential heating. ETS (environmental tobacco smoke), home cooking and heating are the most significant indoor sources of airborne PAH (Chuang et al., 1991;Jedrychowski et al., 2002;Klepeis et al., 1999;Wallace, 2000). Krakow, Poland is an industrialized city with high ambient PAH attributed to multiple sources, including coal burning for industrial purposes and home heating (Perera et al. 1998). There is an estimated 2-fold variation in annual average ambient PAH between the high and low pollution areas of Krakow (Jedrychowski et al., 2002.).

* Contact author email: kp2014@columbia.edu

Our previous results have shown an association between PAH exposure among Krakow newborns and adverse birth outcomes (Perera et al. 1998.).

METHODS

The women in this study are part of an ongoing prospective cohort study of pregnant women in Krakow who have resided for the past year within a 0.5 km radius of the ambient air monitoring stations with either the highest (the Srodmiescie sector) or lowest (the Krowodrza sector) PAH levels (Jedrychowski, et al. 2002.). Study protocols have been described in detail previously (Jedrychowski, et al. 2002.). In summary, non-smoking pregnant women are recruited toward the end of the 1st trimester of pregnancy (between the 8th and 13th weeks) continuously throughout the year to maximize the variability in ambient pollution levels. Enrollees are restricted to women > 18 years of age. Women are excluded if they have a history of using illicit drugs, have potential occupational exposures to PAH or other developmental toxicants, or a history of pregnancy-related diabetes or hypertension. Women are recruited in the high and low pollution areas in Krakow. At enrollment, information on age, ethnicity, sex and health status is collected using a standardized questionnaire. Medical records are reviewed for medical diagnoses and prescribed medications and detail questionnaires are administered to the women during the 1st, 2nd, and 3rd trimesters. They elicits demographic data, SES, residential history, active and passive smoking history, home characteristics, daily activity patterns, occupational history, alcohol and caffeine use during each trimester of pregnancy, and dietary consumption of PAH-containing foods.

The air monitoring is conducted on all women over 48-hours during the 2nd trimester. Indoor air is collected in the main activity room of the home; outdoor air is collected by placing the sampler in a window of the home; and personal air is collected by placing the sampler in a backpack which the woman is instructed to wear during the day and place by her bed at night. All sampling pumps operate at 2 liters per minute collecting particles of ≤ 2.5 microns on pre-cleaned quartz filter and vapors and aerosols on a polyurethane foam (PUF) plug. Air samples are soxhlet-extracted with 6% diethyl ether in hexanes, and analyzed by GC/MS selected ion monitoring.

The current report presents results of the indoor, outdoor and personal monitoring during the 2nd trimester of pregnancy for the initial 27 women in the cohort. The monitoring was conducted between January, 2001 and August, 2001. Mean, standard deviations and the range in PAH concentrations (ng/m^3) were calculated. Spearman's rank was used to examine the correlations between personal, indoor and outdoor PAH measurements. Levels of benz(a)anthracene by month of the monitoring were calculated as a representative PAH in order to examine season variation in exposure levels.

RESULTS

Demographic characteristics are presented in Table 1.

Table 1. Demographic characteristics

N=27

Age groups:		**Education**	
<=20	2 (7.4%)	< college –	12(44.4%)
20 – 30	18 (66.6%)	>college -	15 (55.5%)
>30	7 (25.9%)		
Marital status:		**Income**	
Married –	26 (96.3%)	Tax 19%	16 (59.3%)
		Tax 30%	1 (3.7%)
		unreported	7 (25.9%)

The results of indoor, outdoor and personal PAH exposure is presented in Table 2. Spearman's analysis shows highly correlated values (all r values>0.93) between the indoor, outdoor and personal exposure levels (Table 3). The personal PAH concentrations are lower than or similar to outdoor levels and are consistently higher than the indoor PAH concentrations.

Table 2. PAH levels (ng/m3) in 48-hours personal, indoor and outdoor measurements during the second trimester of pregnancy.

N=27

Mean ± SD (range)

	Personal	Indoor	Outdoor
Benz(a)anthracene	6.00±9.10(0.39-36.69)	4.81±6.47(0.38-26.82)	8.54±12.74(0.37-55.39)
Benzo(b)fluoranthene	6.79±8.53(0.42-32.64)	5.46±6.24(0.48-25.96)	8.77±9.70(0.47-38.32)
Benzo(k)fluoranthene	2.12±2.73(0.18-11.25)	1.68±1.86(0.19-7.39)	2.65±3.12(0.18-13.11)
Benzo(a)pyrene	5.78±8.65(0.24-36.79)	4.45±5.72(0.23-22.97)	5.66±7.56(0.23-29.42)
Chrysene/iso-Chrysene	4.57±6.66(0.34-29.72)	3.45±4.19(0.35-17.00)	6.83±8.65(0.39-38.13)
Dibenz(a,h)anthracene	1.32±1.91(0.17-9.41)	1.12±1.26(0.17-5.79)	1.35±1.70(0.17-8.15)
Indeno(1,2,3-cd)pyrene	6.90±10.00(0.55-50.20)	5.37±6.67(0.46-32.71)	6.52±7.18(0.39-31.42)
Pyrene	8.07±10.09(1.46-47.12)	6.57±6.76(1.25-31.06)	12.73±16.06(1.36-78.9)

Table 3. Correlation coefficient (r-Spearman's rank correlation coefficients)

	Personal vs indoor	Personal vs outdoor	Indoor vs Outdoor
Benz(a)anthracene	0.9609	0.9670	0.9683
Benzo(b)fluoranthene	0.9725	0.9670	0.9792
Benzo(k)fluoranthene	0.9798	0.9530	0.9786
Benzo(a)pyrene	0.9567	0.9640	0.9878
Chrysene/iso-Chrysene	0.9499	0.9341	0.9548
Dibenz(a,h)anthracene	0.9371	0.9841	0.9371
Indeno(1,2,3-cd)pyrene	0.9750	0.9750	0.9835
Pyrene	0.9628	0.9432	0.9646

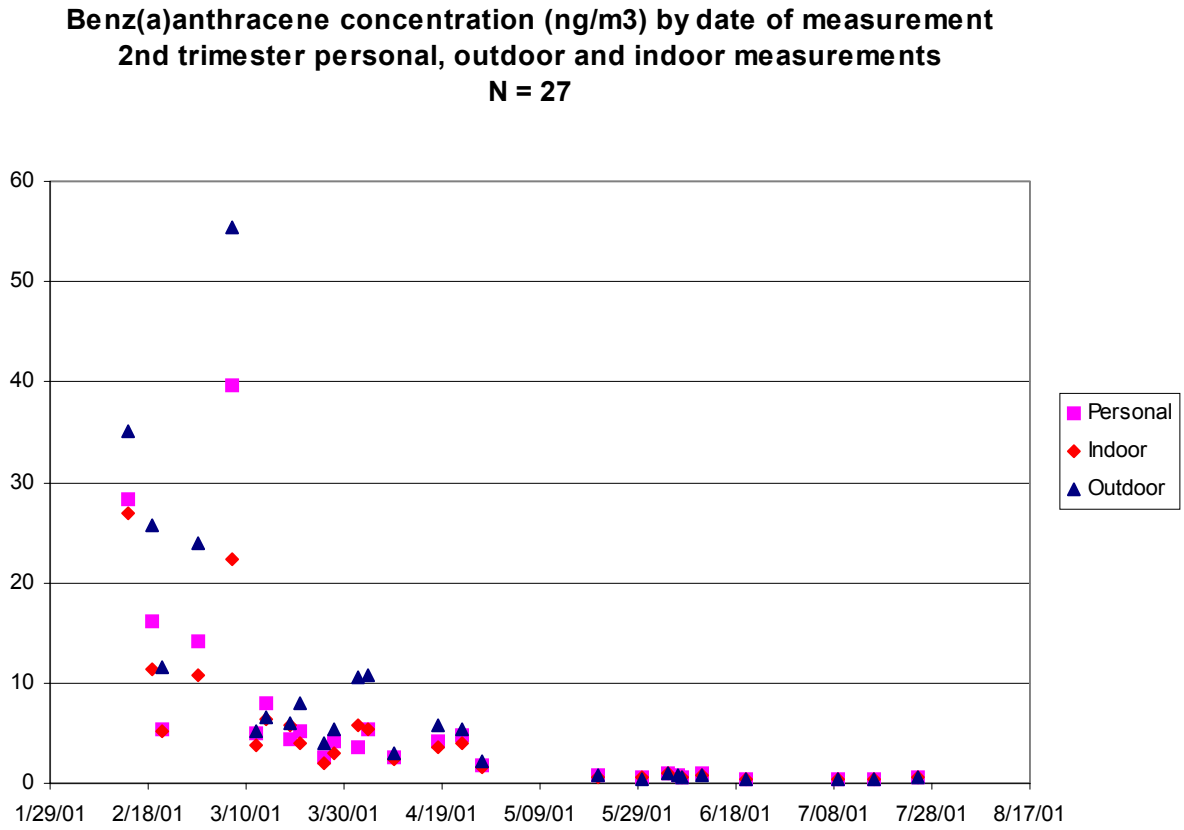

Figure 1 shows benz(a)anthracene levels by the months of the monitoring. Concentrations are highest in winter months and lowest in summer months.

DISCUSSION AND IMPLICATIONS

These results show evidence of widespread exposures to various PAH compounds in this cohort of pregnant women from Krakow, Poland. The PAH showing the highest concentration in personal, indoor and outdoor were benzo(b)fluoranthene and benz(a)anthracene (ng/m3) for which data on health effects are limited. Exposures to all 8 PAH were considerably higher than concentrations that have been measured in a cohort of pregnant women from New York City (Jedrychowski, W, Whyatt, R, Camann, D, et al. 2002.). Coal burning for heating and industry is suspected as a source of the ambient PAH in Krakow (Perera, FP, Whyatt, RM, Jedrychowski, W, et al. 1998.). Our findings that levels were significantly higher during the winter than the summer months is consistent with this hypothesis. In addition, the heavy traffic concentrations in Krakow may also contribute to the ambient PAH. Unlike some earlier finding (Ando M; Tamura K., 1991.) (Liu Y, Zhu L. S. X., 2001.),(Liu Y, Zhu L. S. X., 2001.) we found that the PAH were highest in the outdoor samples and lowest in the indoor samples. Personal levels were higher than indoor and were similar to or lower than outdoor levels. Indoor, outdoor and personal monitoring PAH were all highly correlated ($r>0.93$). Collectively, these initial findings suggest the possibility that ambient PAH is a significant source of both personal and indoor PAH exposures among this cohort. As mentioned earlier, the women in this study are part of an ongoing large-scale prospective cohort study of pregnant women in Krakow. In total, we plan to collect detailed exposure histories and conduct air monitoring on 400 women in the cohort. This will allow us to study in depth the sources of personal PAH exposure during pregnancy. The newborns in the cohort are being followed and the effect of prenatal PAH on infant growth and neurocognitive development will also be assessed.

ACKNOWLEDGEMENTS
This work was supported by NIEHS ES 10165.

REFERENCES

Aceves M, Grimalt JO. 1993. Seasonally dependent size distributions of aliphatic and polycyclic aromatic hydrocarbons in urban aerosols from densely populated areas. *Environ Sci Technol*, Vol. 27 pp 2896-908.

Ando M, Tamura K. 1991. Study of respirable suspended particulates and polycyclic aromatic hydrocarbons in indoor and outdoor air. *Toxicol Ind Health* , Vol. 7 (5-6), pp 441-8.

Chuang JC, Mack GA, Kuhlman MR, et al. 1991. Polycyclic aromatic hydrocarbons and their derivatives in indoor and outdoor air in an eight-home study. *Atmos Environ*, Vol. 25B, pp 369-80.

Jedrychowski W, Whyatt R, Camann D, et al. Effect of prenatal PAH exposure on birth outcomes and neurocognitive development among a cohort of polish mothers and newborns. Study design and preliminary ambient air. *European Epimarker*, Vol. 6 (1), pp 1-6.

Klepeis NE, Ott WR, Repace JL. 1999. The effect of cigar smoking on indoor levels of carbon monoxide and particles. *J Expo Anal Environ Epidemiol*, Vol. 9 (6), pp 622-35.

Lewtas J. 1994. Human exposure to complex mixtures of air pollutants. *Toxicol Lett*, Vol. 72, pp 163-9.

Liu Y, Zhu L. S. X., 2001. Polycyclic aromatic hydrocarbons (PAHs) in indoor and outdoor air of hangzhou, china. *Environ Sci Technol*, Vol. 35 (5), pp 840-4.

Perera FP, Whyatt RM, Jedrychowski W, et al. 1998. Recent developments in molecular epidemiology: a study of the effects of environmental polycylic aromatic hyrdrocarbons on birth outcomes in Poland. *Am J Epidemiol*, Vol. 147 (3), pp 309-14.

Wallace L. 2000. Real time monitoring of particles, PAH, and CO in an occupied townhouse. *Appl Occup Environ Hyg*, Vol. 15 (1), pp 39-47.