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VOC findings and personal exposure models

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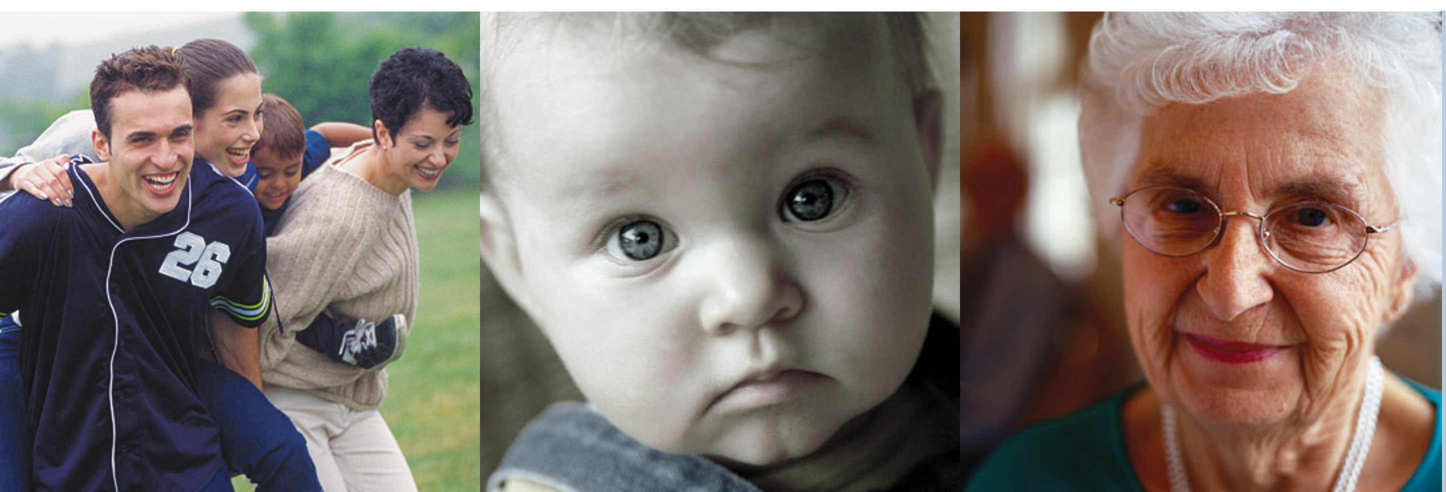


Canada

Exposure Assessment Objectives:

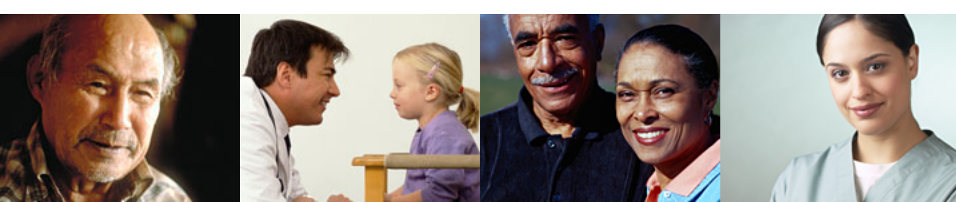
- Understand exposure patterns of individuals;
- Describe air pollution levels within a Canadian city;
- Investigate the relationships between indoor, outdoor, and personal concentrations of different VOCs and other air pollutants;
- Identify differences in exposure through the development of personal exposure models for risk management purposes

Study Design

- Conducted in Windsor, ON in 2005 and 2006
- Personal, Indoor, Outdoor Concentrations were measured for:
  - 188 VOCs using Summa Canisters
  - NO_2 and O_3 using Ogawa Passive Badges
  - $PM_{2.5}$ using R&P Chempass Multi-pollutant Sampler
- Collected self-report questionnaire data via daily questionnaires, baseline housing survey, and time activity diaries.
- In 2005, study population was primarily female, Caucasian, and working within the home
- In 2006, study population was asthmatic children age 10 - 12

Geometric Mean Concentration of CEPA TOXIC VOCs

VOC	MDL	% Below Detection Limit		Indoor GM (µg/m3)		Outdoor GM (µg/m3)		Personal GM (µg/m3)	
		Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
1,1,1- Trichloroethane	0.01	0.00	0.00	0.222*	0.298*	0.132*	0.127*	0.20	0.30
1,2- Dichloroethane	0.01	0.00	0.20	0.10	0.19	0.043*	0.036*	0.10	0.23
1,3-Butadiene	0.01	0.20	0.00	0.128*	0.113*	0.07	0.05	0.160*	0.143*
Acetaldehyde	0.01	0.00	0.30	18.44	39.63	3.51	6.64	19.97	39.46
Acrolein	0.03	3.30	0.60	1.29	5.02	0.14	0.58	1.16	4.04
Acrylonitrile	0.03	96.40	93.10	<0.031	<0.031	<0.031	<0.031	<0.031	<0.031
Benzene	0.01	0.00	0.00	1.682*	1.953*	0.969*	0.786*	1.685*	1.957*
Dichloromethane	0.00	0.00	0.00	0.93	1.56	0.32	0.39	1.304*	1.692*
Ethylene Oxide	0.06	94.90	59.40	<0.062	<0.062	<0.062	0.11	<0.062	0.07
Hexachlorobutadiene	0.01	92.00	86.10	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014
Vinylchloride	0.00	15.80	41.20	0.00	0.00	0.00	0.00	0.005*	0.006*



CEPA Toxic VOC's

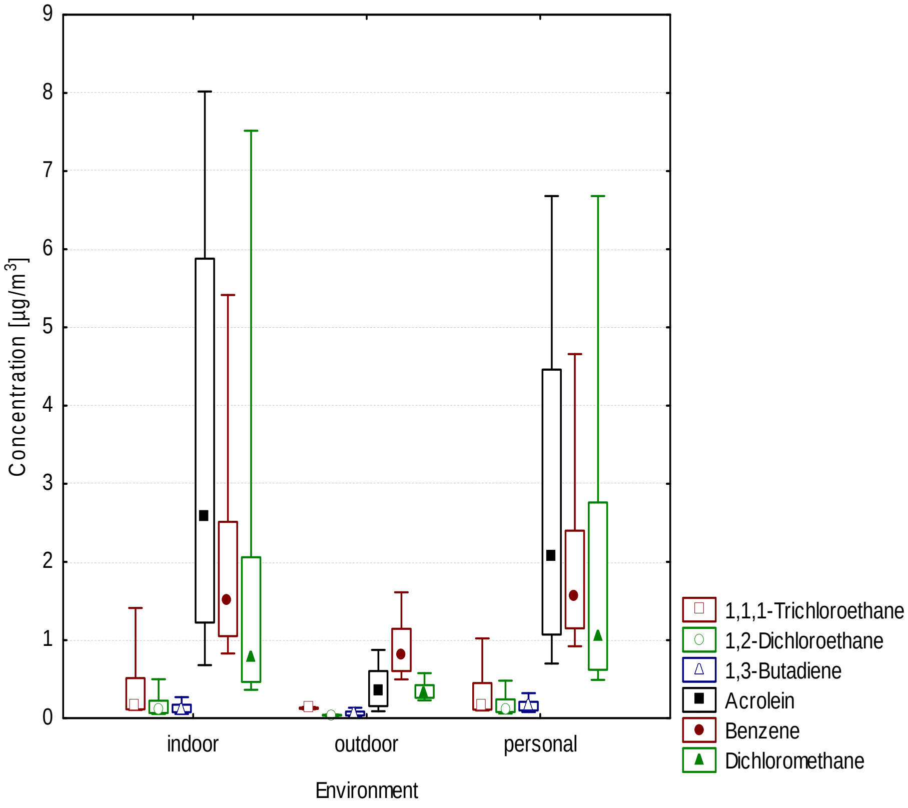
- Acrylonitrile, ethylene oxide, hexachlorobutadiene, and vinylchloride were removed from further analysis due to high percentage of non-detects
- With the exception of 1,1,1-trichloroethane, 1,3-butadiene, benzene and dichloromethane, all CEPA toxic VOCs were significantly higher in summer than in winter in all three locations.
- 1,3-butadiene was consistently lower in summer across all measures.
  - Potentially due to increased atmospheric reactivity

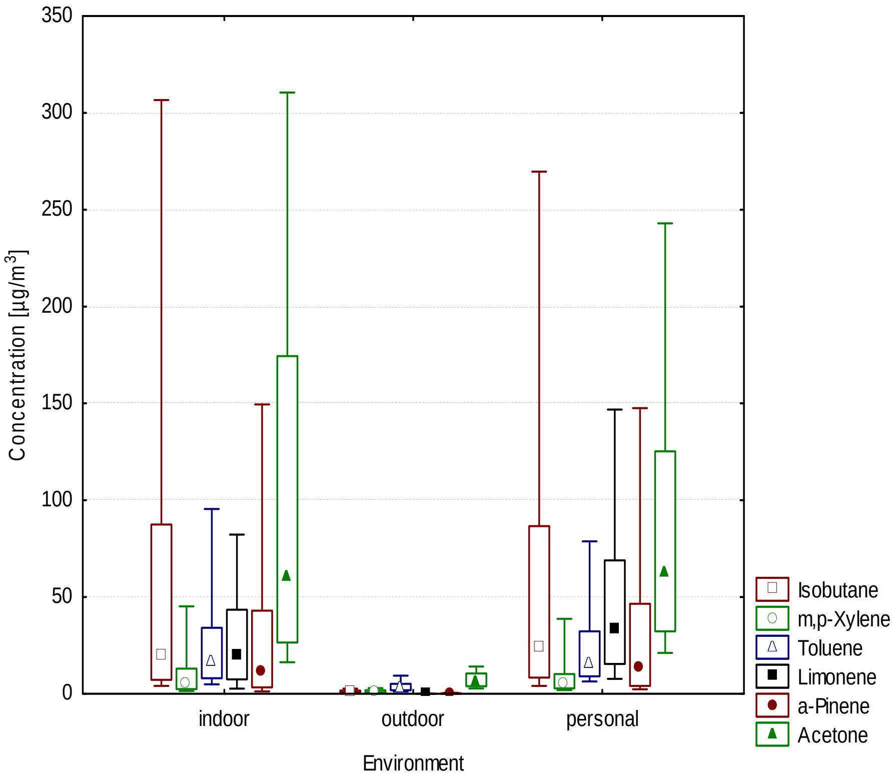
Geometric Mean Concentration of Commonly Found VOCs

VOC	MDL	% Below Detection Limit		Indoor GM (µg/m3)		Outdoor GM (µg/m3)		Personal GM (µg/m3)	
a-Pinene	0.01	2.00	0.20	4.51	26.69	0.04	0.33	6.88	29.75
Acetone	0.01	0.00	0.60	32.15	137.01	4.04	10.01	38.74	115.83
Ethanol	0.03	0.20	0.20	713.15	1168.70	4.30	6.70	661.42	1022.71
Isobutane	0.01	0.00	0.00	18.54	35.94	1.394*	1.104*	23.509*	34.391*
Limonene	0.01	7.70	1.20	9.91	19.80	0.03	0.09	22.14	47.90
m,p-Xylene	0.01	0.20	0.00	4.43	11.15	0.85	1.63	5.04	10.06
Toluene	0.00	0.00	0.00	11.95	30.14	2.51	4.61	13.90	24.90

***not statistically significant different ($p<0.05$) across seasons**

Concentrations of 14 VOCs





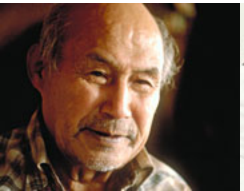
Indoor concentrations closely related to personal concentrations, and were much higher than outdoor concentrations

Determinants of Personal Exposure (CEPA TOXIC VOCs):

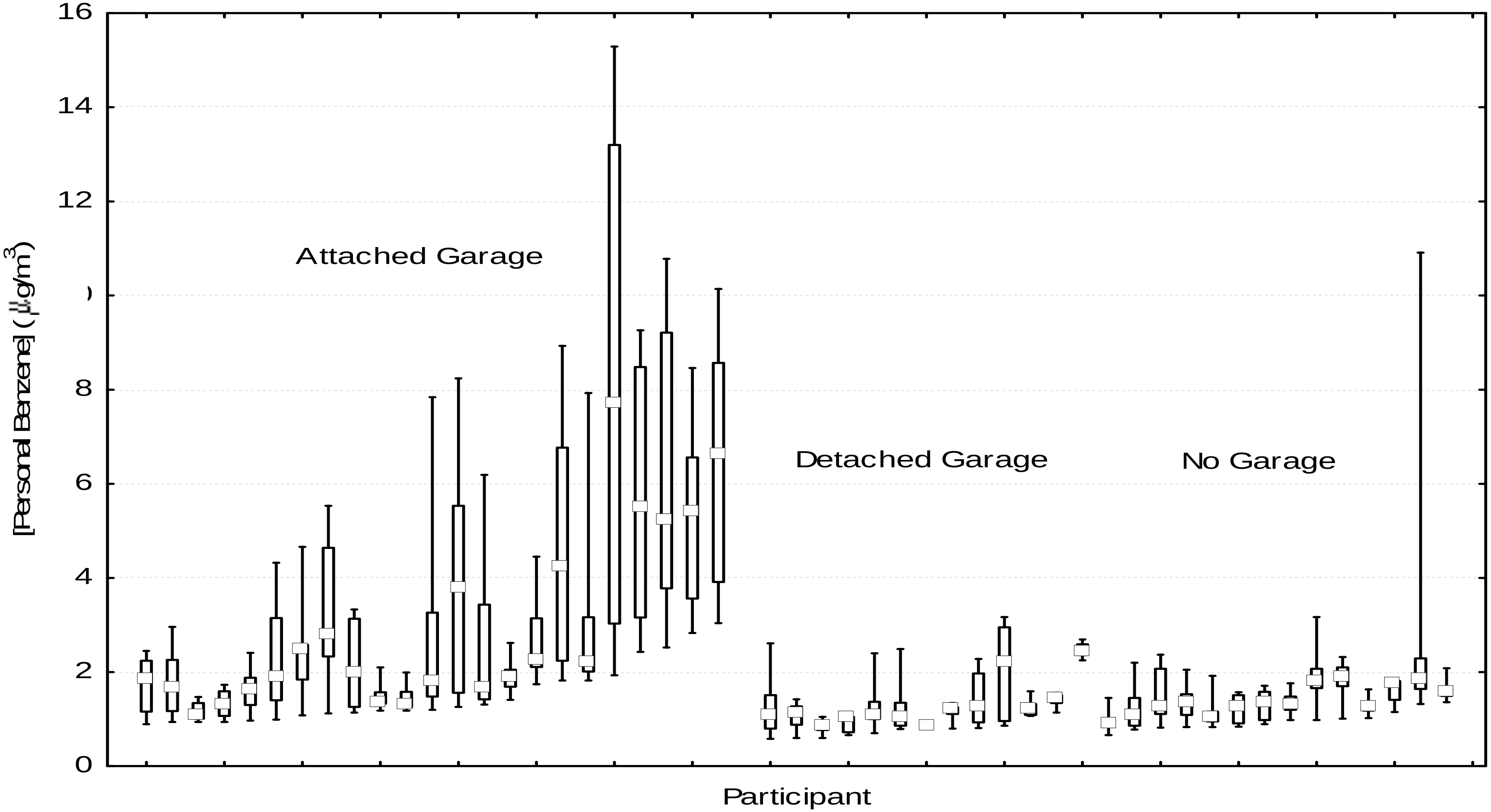
including indoor concentration			excluding indoor concentration		
	p	***r^2**		***p***	***r^2**
ln(1, 3-Butadiene)		***57.8%***	**ln(1, 3-Butadiene)**		***30.6%***
Intercept	0.0482		Intercept	<0.0001	
ln indoor 1,3-butadiene	<0.0001		Garage Use	0.0296	
ln outdoor 1,3-butadiene	0.0105		Garage Type	0.0212	
			ln outdoor 1,3 butadiene	<0.001	
ln(Acetaldehyde)		***58.4%***	**ln(Acetaldehyde)**		***49.8%***
Intercept	<0.0001		Intercept	<0.0001	
ln indoor acetaldehyde	<0.0001		Air Exhange Rate/h	<0.0001	
Air Exchange Rate/h	<0.0001		Season	<0.0001	
Season	<0.0001				
ln(Benzene)		***87.2%***	**ln(Benzene)**		***40.5%***
Intercept	<0.0001		Intercept	<0.0001	
ln indoor benzene	<0.0001		Garage Type	<0.0001	
Air Exchange Rate/h	0.0097		ln outdoor benzene	<0.0001	
			Air Exchange Rate/h	0.0003	
			Season	0.0197	
ln (acrolein)		***75.0%***	**ln (acrolein)**		***73.1%***
Intercept (β=0.31)	0.0004		Intercept	<0.0001	
Stove Type	0.0197		Stove Type	0.0029	
Air Exchange Rate/h	<0.0001		Air Exchange Rate/h	<0.0001	
ln indoor acrolein	<0.0001		Season	<0.0001	
Season	<0.0001				

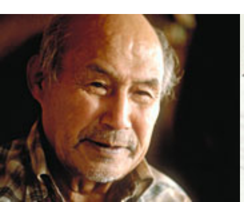
Summary of Personal Exposure Models (CEPA Toxic VOCs)

- Indoor concentrations were highly predictive of personal exposures
- Inclusion of indoor concentrations in the model could predict between 57.8% and 87.2% of the variability in personal exposures
- Exclusion of indoor concentrations reduced this value to 0.01-73.1%
- Higher air exchange rates decreased personal exposure
- Presence of gas stove was an important predictor of personal acrolein
- Garage type was an important predictor of traffic-related VOCs
- Garage use was also important for 1,3-butadiene



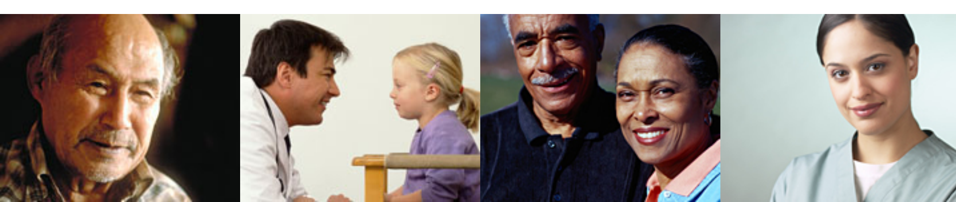

Personal Benzene Concentrations by Garage Type:






Determinants of Personal Exposure (Commonly Found VOCs)

including indoor concentration			excluding indoor concentration		
	p	$*r^2$		*p*	$*r^2$
ln (α-pinene)		*52.0%*	ln (α-pinene)		*42.7%*
Intercept	<0.0001		Intercept	<0.0001	
Air Exchange Rate/h	<0.0001		Air Exchange Rate/h	0.0111	
ln indoor α-pinene	0.0016		Season	0.0012	
Season	<0.0001				
ln (limonene)		*41.7%*	ln (limonene)		*28.4%*
Intercept	<0.0001		Intercept	<0.0001	
ln indoor limonene	<0.0001		Air Exchange Rate/h	0.0008	
Air Exchange Rate/h	0.0024		Air freshener use	0.0087	
Air freshener use	0.0299		Season	0.0011	
Season	0.0013				

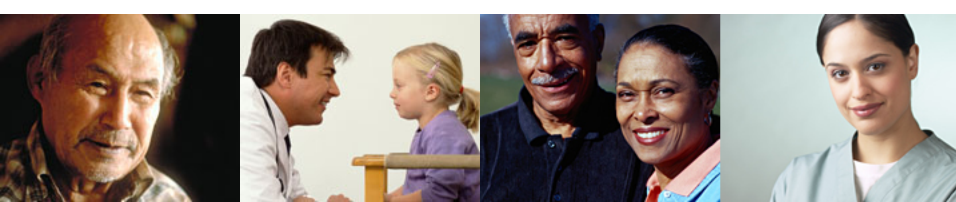


Summary of Personal Exposure Models (Commonly Found VOCs)

- Including indoor concentrations in the exposure models could account for 41.7% - 90.1% of the variability in personal exposures to commonly found VOCs
- Excluding indoor concentrations resulted in a decreased r^2 value (could explain between 0.01% and 43.4% of the variability)
- For the commonly found traffic related VOCs (m,p-xylene, and toluene) garage type was a significant predictor
- Air exchange rate was found to be a significant predictor
- Air freshener use was a significant predictor of limonene.

Conclusions

- Concentrations of the majority of the VOCs were higher in the Summer than in the Winter
- Personal Exposure to VOCs can be largely predicted by indoor concentrations
- Given that people spend the majority of their time indoors, there is much greater potential for exposure to VOCs indoors
- Garage type, garage use, air freshener use, air exchange rate, and stove type were significant predictors of personal exposure
- Geographic predictors were not found to be significant
  - May be a result of low intraurban variability in Windsor or possibly the low predictive ability of outdoor concentrations



Geometric Mean Concentrations of NO_2 (ppb):

	Season	2005		2006	
		geometric mean	% <LDL	geometric mean	% <LDL
indoor	summer	4.19 (2.95-5.94)	10.3	6.17 (5.23-7.28)	0.4
	winter	6.49 (4.90-8.59)	3.0	10.23 (8.69-12.04)	0.4
outdoor	summer	6.82 (4.77-9.75)	10.0	9.64 (8.42-11.04)	0.4
	winter	16.57 (14.61-18.79)	0.4	18.66 (17.06-20.41)	0.0
personal	summer	6.70 (4.91-9.14)	9.6	6.41 (5.71-7.19)	0.0
	winter	7.79 (6.57-9.22)	0.4	11.55 (10.39-12.83)	0.0

Determinants of Personal Exposure (NO_2)

- In 2005, significant predictors were found to be indoor concentrations, outdoor concentrations, stove type, pilot light on the oven or clothes dryer, and length of major roads in 100m buffer

- Models including indoor concentrations could predict 81.5% of the variability, and those excluding indoor concentrations could predict 73.1% of the variability

- In 2006, significant predictors were % of time spent indoors, indoor concentrations, outdoor concentrations, stove type and season

- Models including indoor concentrations could predict 56.6% of the variability, and those excluding indoor concentrations could predict 38.5 % of the variability

Geometric Mean Concentrations of $PM_{2.5}$ ($\mu g/m^3$):

	Season	2005		2006	
		geometric mean	% <LDL	geometric mean	% <LDL
indoor	summer	8.41 (7.12-9.94)	0.0	5.65 (4.83-6.61)	0.5
	winter	6.89 (5.91-8.04)	0.0	6.12 (5.27-7.12)	0.5
outdoor	summer	18.08 (16.05-20.37)	0.0	11.73 (10.60-12.97)	0.4
	winter	15.28 (13.25-17.63)	0.0	9.46 (8.41-10.64)	0.9
personal	summer	10.29 (9.05-11.72)	0.0	7.10 (6.30-8.00)	0.0
	winter	8.55 (7.45-9.82)	0.0	7.94 (7.12-8.85)	0.0

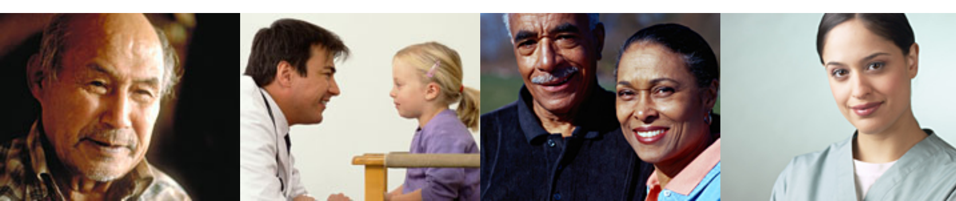
Determinants of Personal Exposure ($PM_{2.5}$)

- In 2005, significant predictors of personal $PM_{2.5}$ exposure were indoor concentrations, outdoor concentrations, presence of controlled ventilation, and distance to Ambassador Bridge

- Models including indoor concentrations could predict 49.5% of the variability, with those excluding indoor concentrations predicting 27.1%

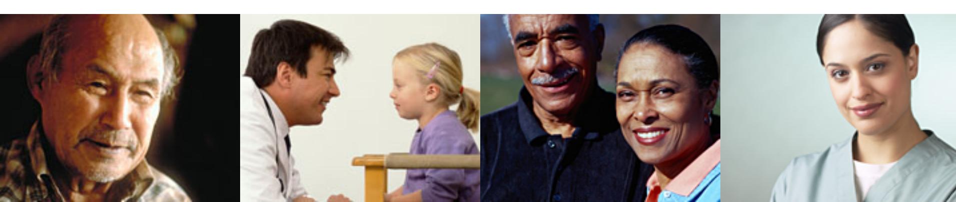
- In 2006, significant predictors were found to be % of day spent indoors, presence of air cleaning devices on the furnace, candle use, presence of open windows, and distance to major roads.

- Models including indoor concentrations in 2006 could predict 62.3% of the variability in personal exposures. When indoor concentrations were excluded, only 35.3% of the variability could be predicted.



Geometric Mean Concentrations of Ozone (ppb):

	Season	2005		2006	
		geometric mean	% <LDL	geometric mean	% <LDL
outdoor	summer	11.61 (10.56-12.67)	3.6	9.63 (8.95-10.30)	4.2
	winter	n/a	-	n/a	-
personal	summer	1.46 (1.18-1.74)	62.2	1.43 (1.15-1.71)	67.3
	winter	n/a	-	n/a	-



Future Plans

- Separate the ambient and the non-ambient component of $PM_{2.5}$
- Analyze elemental carbon data when it becomes available
- Apply models (not shown) based on fixed-site ambient monitors to health effect studies
- Conduct source apportionment modelling for personal exposures

Questions?