Personal Level Exposure Characterizations for the NCS: Rationale, Approaches, and Viability

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Exposure assessment rationales by health outcome...

Priority Health Exposures, Outcomes

Priority Exposures	Examples
Physical Environment	Housing quality, neighborhood
Chemical Exposures	Pesticides, phthalates, heavy metals, BPA
Biologic Environment	Infectious agents, endotoxins, diet
Genetics	Interaction between genes and environment
Psychosocial Milieu	Family structure, socioeconomic status, parenting style, social networks, exposure to media and violence

Priority Health Outcomes	Examples
Pregnancy Outcomes	Preterm, birth defects
Neurodevelopment and Behavior	Autism, learning disabilities, schizophrenia, conduct and behavior problems
Injury	Head trauma, injuries requiring hospitalizations
Asthma	Asthma incidence and exacerbation
Obesity and Physical Development	Obesity, diabetes, altered puberty

No one exposure monitoring approach will work for all target health outcomes and time scales

THE NATIONAL CHILDREN'S STUDY
HEALTH GROWTH ENVIRONMENT

Particulate matter (PM) exposures are the most difficult to address at the personal level

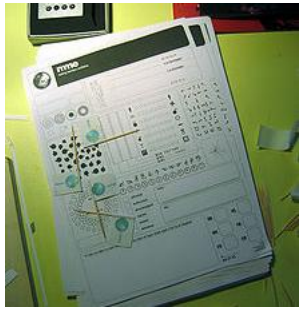
- **Gas rather than particle phase contaminants are simpler given the availability of validated low burden passive exposure monitors, but passive approaches provide no acute level information (e.g. for cardiopulmonary disease outcomes)**
- **Passive aerosol samplers have been developed and are undergoing evaluation (e.g. Ott et al., 2008) but are not discussed here.**
- **Optimal PM monitoring requires more burdensome active sampling to obtained aerodynamic sizing and to collect sufficient sample mass to enable speciation analyses - h*ave we now reached the point where the personal level is becoming viable for large cohort studies?* [Rodes, 2011A]**

Ott, D., Cyrs, W. and T. Peters (2008) "Passive Measurement of Coarse Particulate Matter", J. Aerosol Sc., 39(2):156-167.

Rodes, C. (2011A) "Indoor Aerosol Exposure Assessment", ch. 27 in Aerosol Measurement: Principles, Techniques and Applications, Wiley, New York, NY.

Some of the ways to estimate true breathing zone exposures for a large cohort:

<---simpler, less robust vs more informative, & complex --->

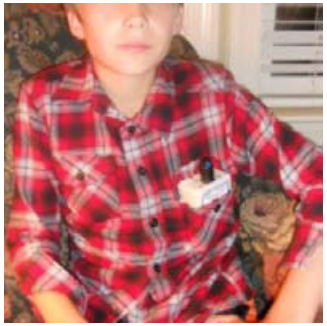


model from questionnaire data

estimate from outdoor measurements

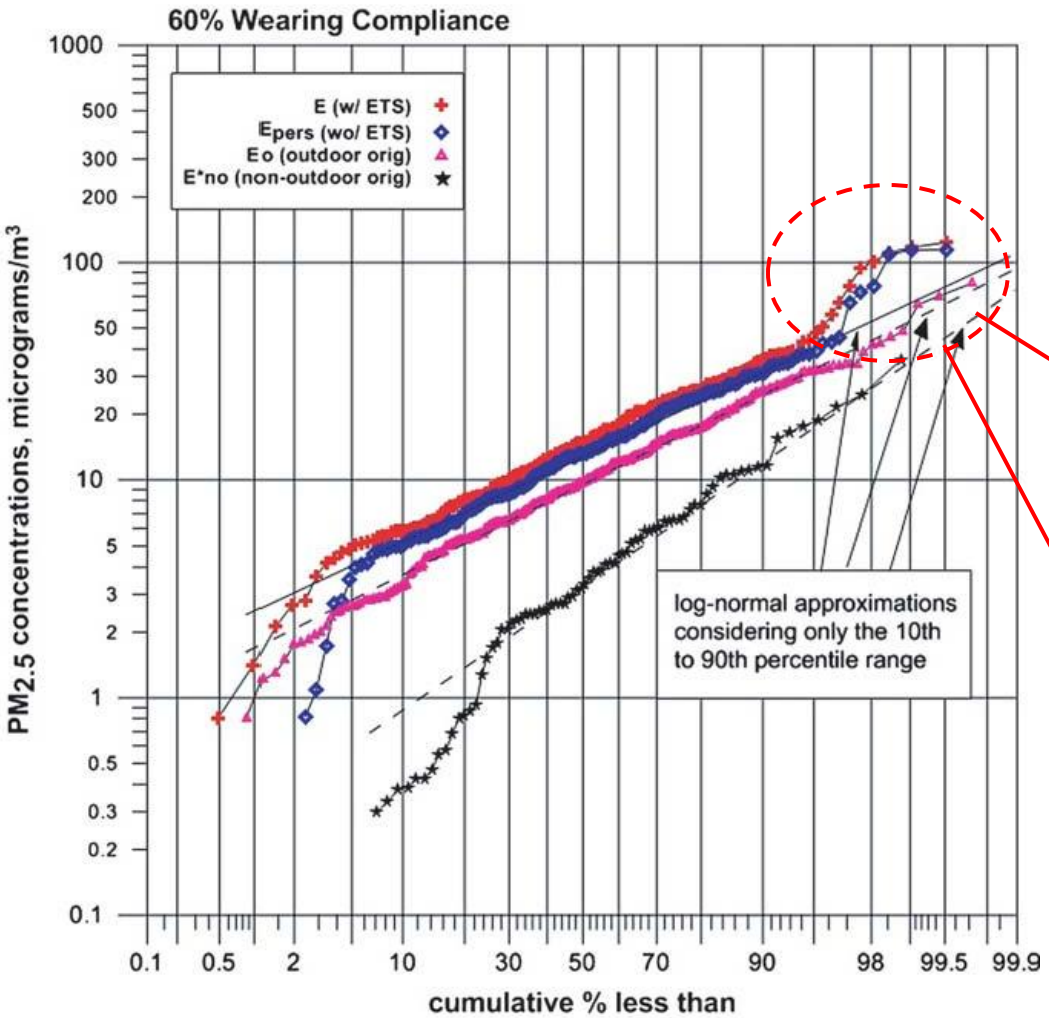
estimate from indoor surrogate measurements (house dust)

estimate from indoor measurements



actual personal measurements (in this case a child of 10)

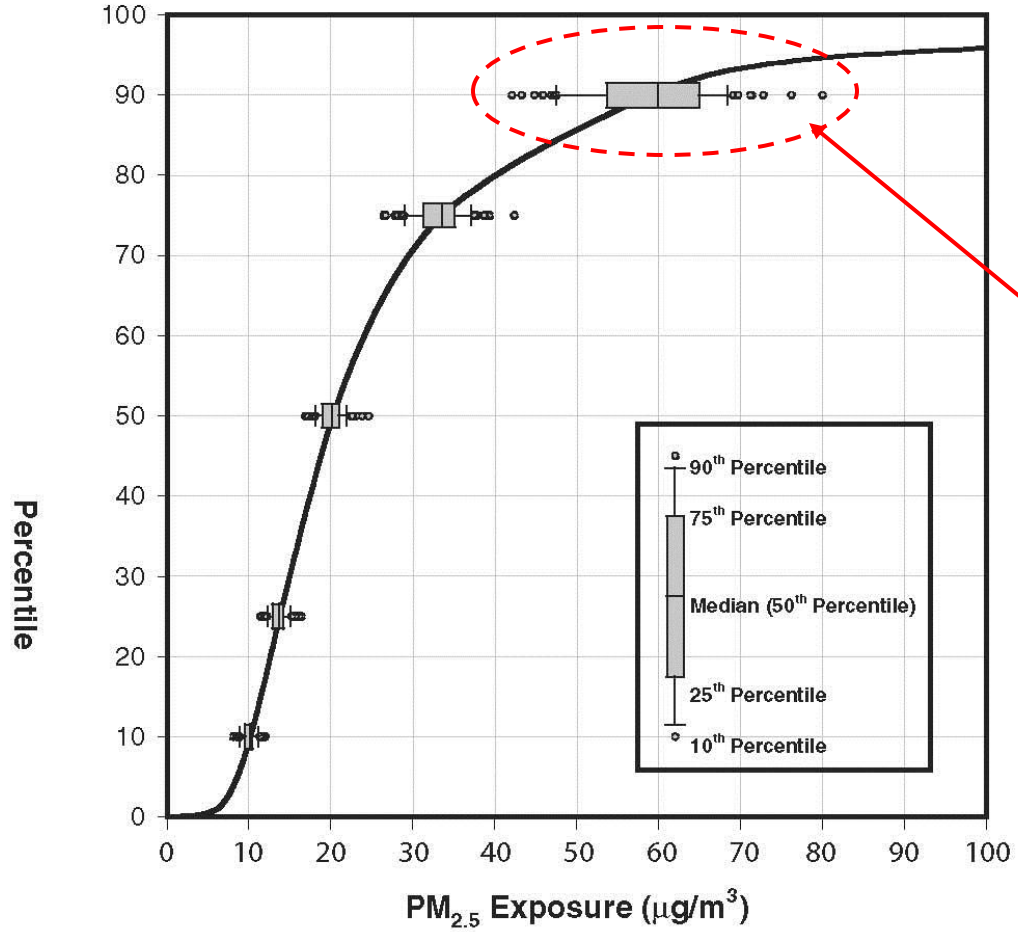
EPA general population DEARS study - Season 4 data



- **PM exposures estimated at outdoor and indoor (non-outdoor) locations are quite log-normal**
- **PM levels for the most exposed deviate significantly from log-normality - and other measures [Rodes et al, 2010**
- **PM exposures above the 90th percentile are very difficult to predict with exposure models**

Rodes et al. (2010) "DEARS Particulate Matter Relationships for Personal, Indoor, Outdoor, and Central Site Settings for a General Population", Atmos. Env., 44:11, 1386-1399. .

Example of how uncertainties vary in surrogate model estimates



- **Figure 4 from Janet Burke et al. (2004) provides an excellent example from Philadelphia using the EPA SHEDS exposure model**
- **Note leveling and dramatic increases in uncertainty range at the 90th percentile**
- **Model validation with personal level assessments would reduce the 90%ile uncertainties to those at 50%ile**

Burke et al. (2004) "A Population Exposure Model for PM: Case Study Results for PM2.5 in Philadelphia", JEAEE, 11:470-489.

Rationales for considering personal-level exposures...

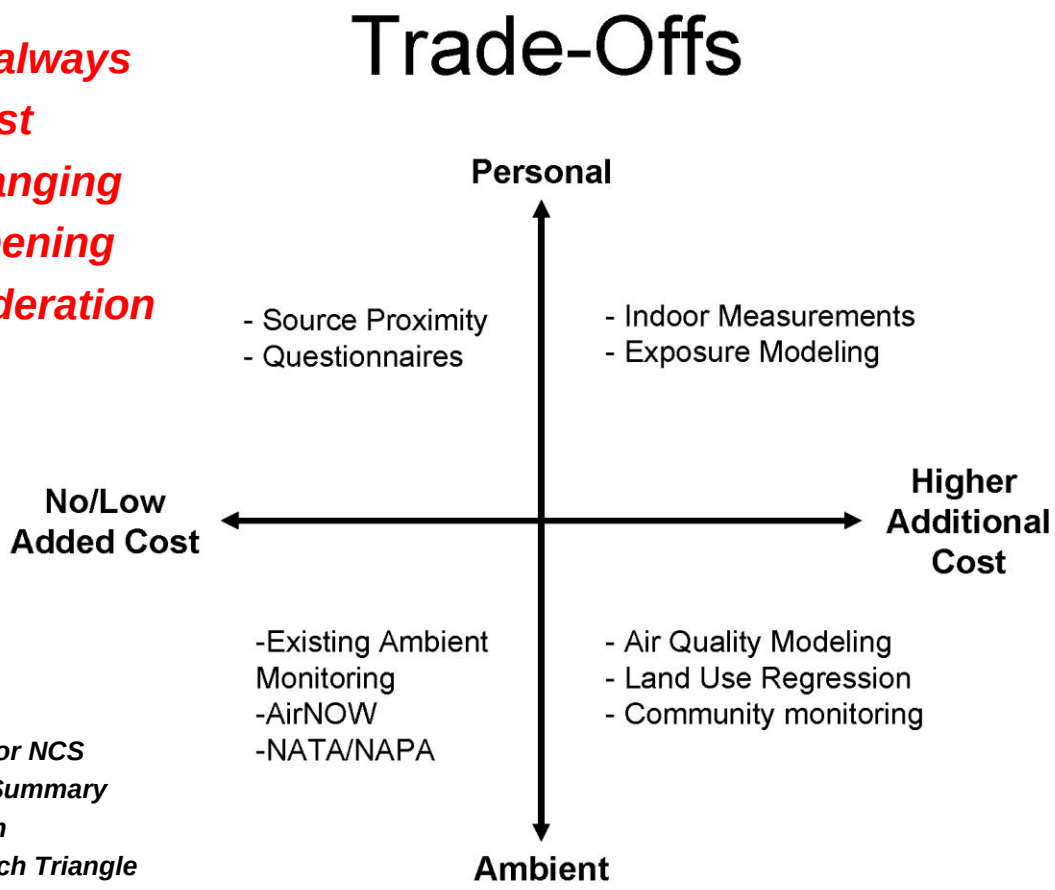
- **Collecting personal samples and data from the breathing zone is the best representation of the inhalation exposure route [Rodes and Thornburg, 2011]**
- **Definitely provides the strongest possible associations with adverse health outcomes for diseases that have been shown to be sensitive to acute time scales - e.g. most pulmonary diseases and many cardivascular responses**
- **Provides information on both levels and patterns of exposure for associative and relative risk analyses, and provide the pathway to defining the strongest mitigation approaches to reduce exposures**
- **Meets the NRC, 2004 mandate to minimize exposure mis-classification erros wherever possible in linking air toxics to adverse health outcomes**

Rodes and Thornburg (2011) "Breathing Zone Exposure and Potential Dose Assessment" in Aerosols Handbook: Measurement, Dosimetry and Health Effects (2nd ed., in press), L. Ruzer & N. Harley, eds., CRC Press, New York, NY.

National Research Council (2004) "Research Priorities for Airborne Particulate Matter IV", National Academies Press, Washington, DC.

Pat Breysse slide ... air exposure approaches have trade-offs

While trade-offs are always on the table, the latest technologies are changing the paradigm and opening new doors for consideration by the NCS



Breysse, P. (2010) "Exposure Metrics for NCS Asthma Investigations", presented at Summary and Recommendations Workshop from Workgroup 1, USEPA, April 12, Research Triangle Park, NC

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Selected personal device features - then and now...

1996

2008

2010

2011

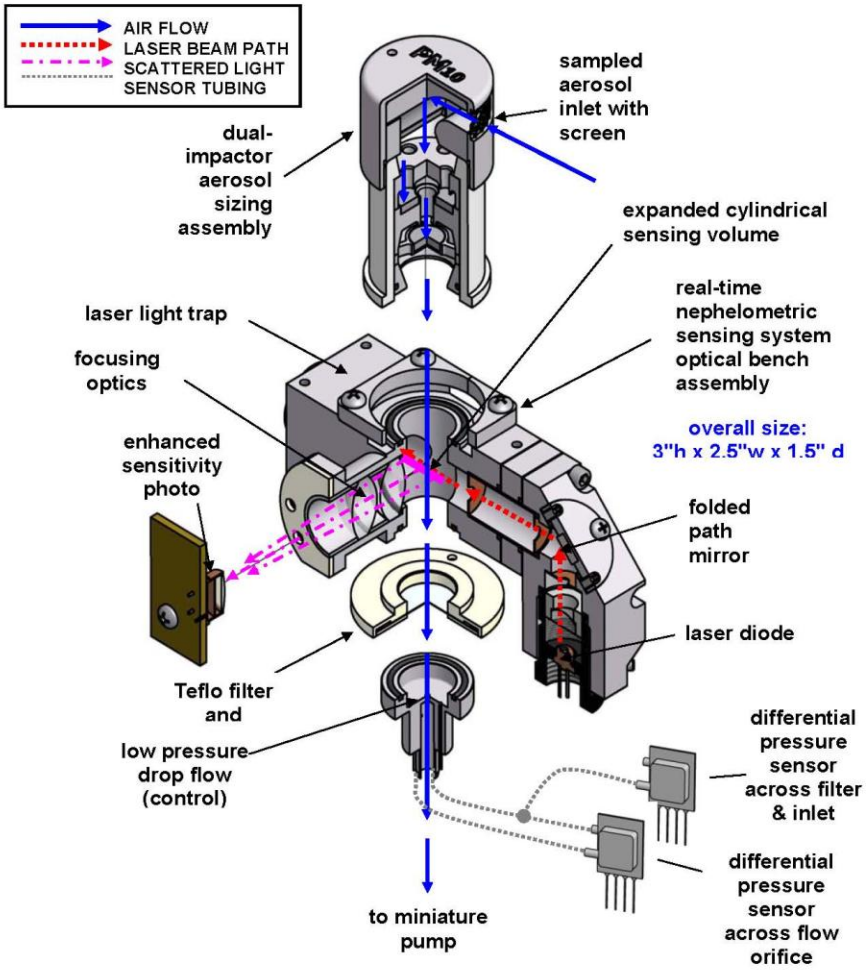
Feature	NHEXAS	EPA DEARS	NIEHS v 2.7	CDC v 3.2
Small, light, and quiet	no, 1,400 g	no, 900g	yes, 300g	<240g; only 38 dBA
Chronic exposure?	yes	yes	yes	yes
Acute exposure	no	not in one unit	yes	yes
Activity/compliance sensing?	no	yes, crudely	yes	yes
QC data collected on-board?	no	comply, T	yes	yes
Power efficient?	not bad	not bad	yes - 36 hrs	yes 168 hrs
Ventilation; potential dose?	no	no	yes	yes
Cost effective?	not a goal	not a goal	no, $4.4k	yes, $2.0k
Easy to use?	not a goal; tech. assist	not a goal; tech. assist	yes - friendly GUI	yes - friendly GUI; potential mail-out

more likely to be NCS-friendly >>>>

How does the RTI MicroPEM™ work?...

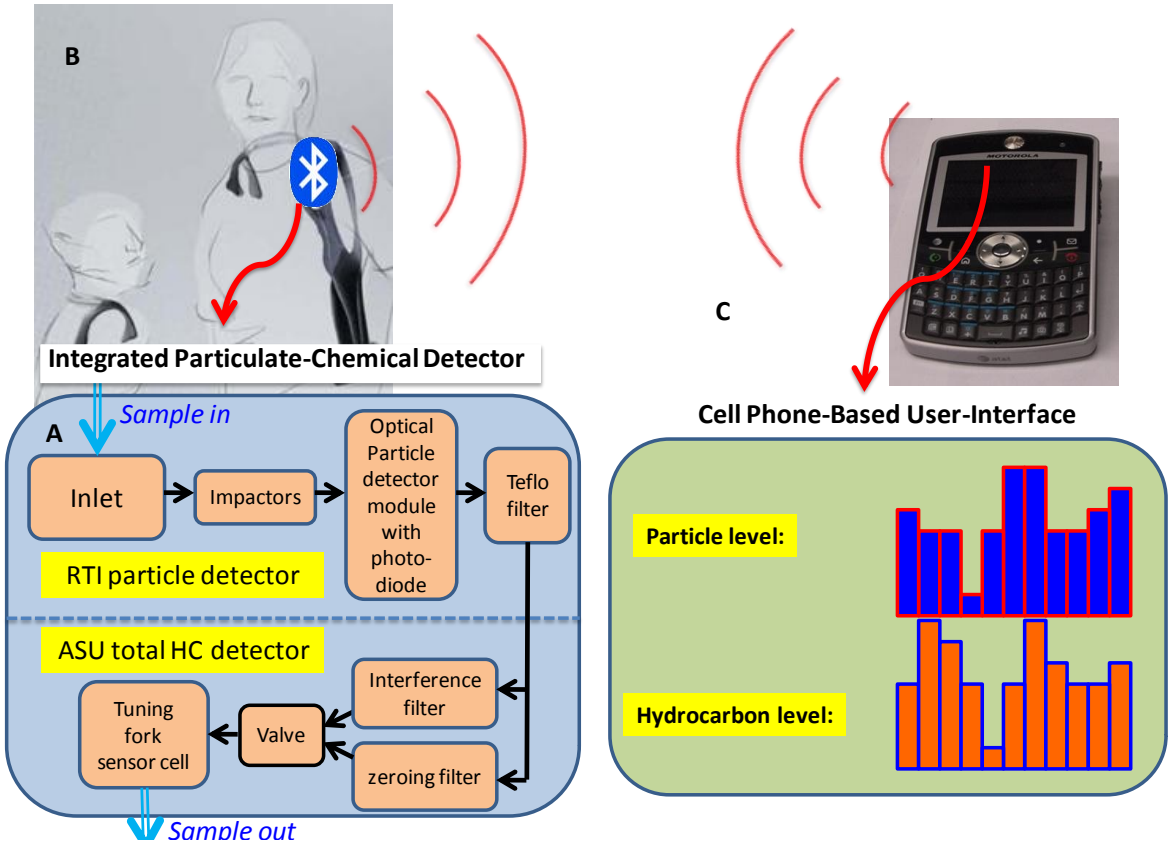
Fully integrated, fully automatic sensor/sampler in a tiny package:

- ***Sized aerosol concentrations estimated by laser-illuminated light scattering (nephelometery) in real-time, with total sampled aerosol captured at low face-velocity on a filter at 0.5 lpm for gravimetric and other post analyses***
- ***On-board software code defines functionalities and manages timing and power, and self-collects QC in the on-board memory for post validation***
- ***Docking Station software allow study PI to define the operating parameters, and controls up- and down-loading of PM and QC data***



Other robust GEI technologies are maturing and also addressing smaller, lighter, and lower cost device targets, e.g. ...

Columbia Univ.
Steve Chillrud, PI
black carbon/SHS sensor



Arizona State Univ.
NJ Tao, PI
HC/PM sensor

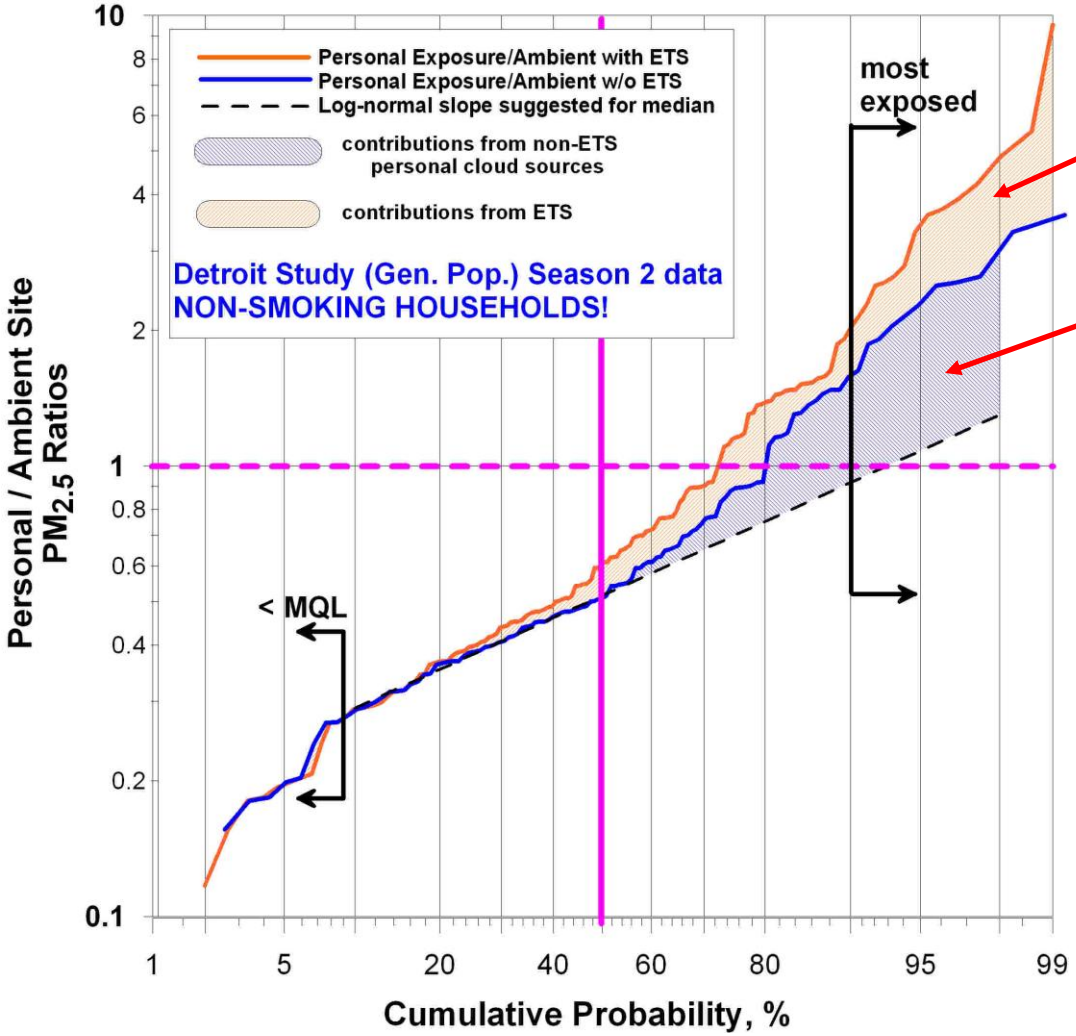
see also Negi et al. (2011) "Novel Monitor Paradigm for Real Time Exposure Assessment", JESEE, 21:419-426.

Logistical and confounding issues must be addressed ...

- **Wearing compliance with personal monitors has not been a problem with challenged cohorts (e.g. asthmatic children, adults with COPD), but can be a huge problem in general population studies**
- **EPA DEARS found that 1/3 of the general population did not wear the (burdensome) monitor 50% of the time**
- ***A simple on-board triaxial accelerometer allows real-time tracking of motion***
- **Also, Second Hand Smoke (SHS) exposures can be much larger than expected and not addressing the confounding to exposure samples will weaken exposure-outcome associations - *monitoring the fraction of collections that area attributable to SHS is now low cost and routine* [Lawless et al., 2004]**

Lawless, P., Rodes, C. and D. Ensor (2004) "Multi-Wavelength Absorbance of Filter Deposits for Determination of Environmental Tobacco Smoke and Black Carbon", Atmos. Env., 38:3373-3383.

SHS confounding impacts the most exposed ...



SHS/ETS confounding

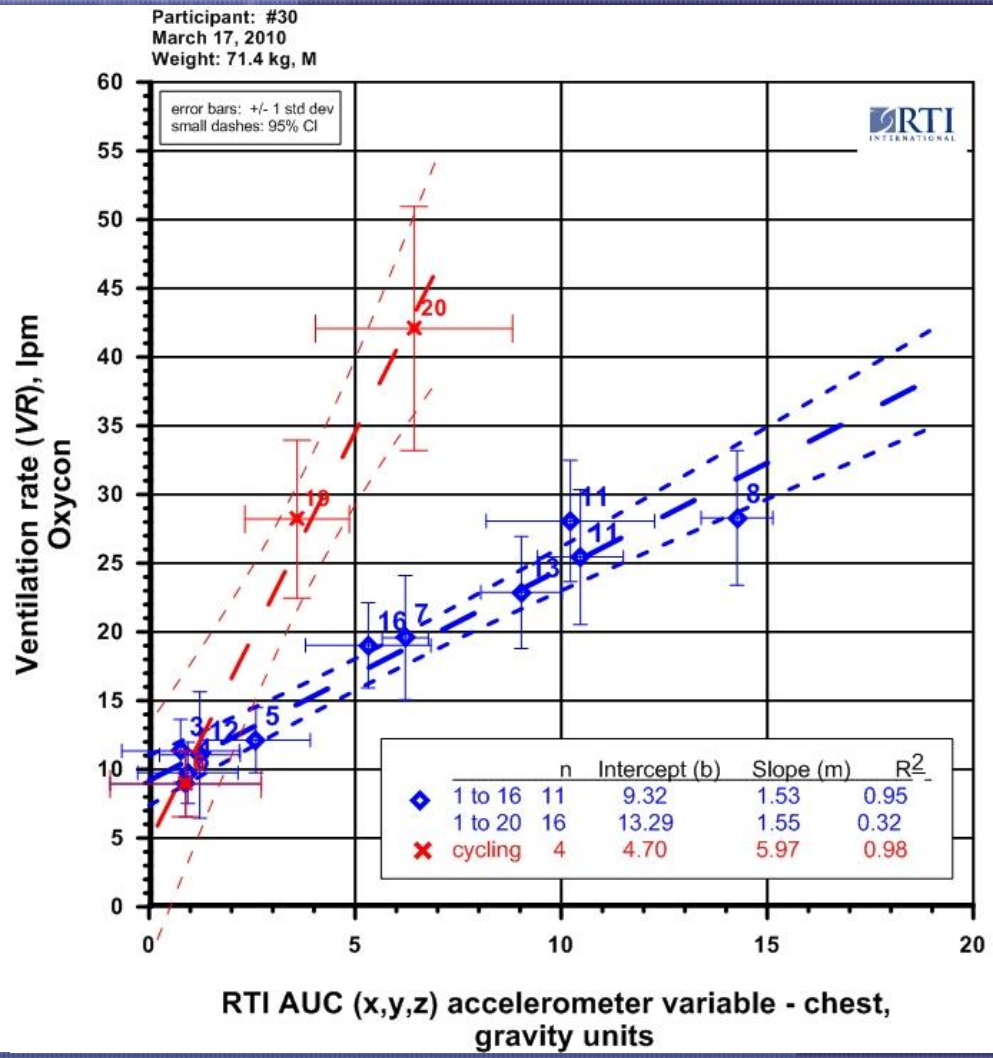
other sources

Per Edwards and Jantunen (2009) the chemistry of the IQR is rarely the same as for the most (or least) exposed!

Rodes et al (2010) "DEARS Particulate Matter Relationships for Personal, Indoor, Outdoor, and Central Site Settings for a General Population", Atmos. Env., 44:11, 1386-1399.

Edwards, R. and M. Jantunen (2009) "Subgroups Exposed to Systematically Different Elemental Compositions of PM2.5", Atmos. Env., 43:3571-3578.

Exciting new possibility to predict ventilation in real time from on-board triaxial accelerometers in personal sensors ...



- Figure 5 in Rodes et al. (2011B) shows strong linearity between ACCEL and vent. rate for most low energy activities for <u>adults</u>
- Allows estimates of potential dose (mg/min/kg) to better link with outcomes
- Potential activity type ID
- A children's data set is awaiting processing in the same manner

Rodes, C., Chillrud, S., Haskell, W., Intille, S., Albinali, F. and M. Rosenberger (2011B) "Predicting Adult Pulmonary Ventilation Volume and Wearing Compliance by On-Board Accelerometry During Personal Level Exposure Assessment", submittal draft for EHP, July, 2011, RTI International, RTP, NC 27709

Pragmatic concerns for personal exposures...

- Are low burden personal approaches (low weight and size, and noise levels; easily wearable and acceptable to cohort) available for the target pollutants?
- Is it feasible to consider multiple pollutant sensors in the same package (e.g. PM and black carbon, or PM and HC's)
- Recent Chillrud/Rodes testing has shown that elementary age children were not happy with 300+g personal monitors operating at 40 dBA in a multi-day longitudinal design, but were much more comfortable with lighter units (nearer to 200g) or more comfortable vests) and with lowered noise levels approaching 38 dBA.
- Recent RTI focus group testing for CDC showed that the wearing method is also critical for children so the devices are relatively transparent to daily activities and social settings (some children do not want to stand out)
- Being able to mail the monitor to a participant with simple starting and "wearing" instructions reduces deployment costs and complexity substantially.

Recommendations

- **The NCS should include subset personal level sampling to better characterize the most- and least-exposed to:**
  - ***provide uniform uncertainty levels across exposure distributions and more clearly define the data ranges***
  - ***develop the most robust associations between environmental exposures and adverse health outcomes - whether acute or chronic time scales***
  - ***achieve statistically-significant associations with the fewest participants and in the shortest time period***

How the NCS program can help...

- ✓ Devise subset exposure monitoring programs at the personal level for PM and other toxics to provide equivalent data quality across exposure distributions to support the most robust epi analyses
- ✓ Define targets for hardware developers for acceptable burden levels for collecting personal level exposures across the range of life stages within the NCS
- ✓ Define and publish targets for device purchase cost and cost per data point requirements that are reasonable for the NCS program
- ✓ Consider alternate analytical schemes for the smaller sample collections likely at the personal level
- ✓ Work with the NIH GEI program and other sensor development initiatives to identify and test/validate the most promising candidates for the future of the NCS

THANK YOU !