Biomass Cookstoves Use in Sri Lanka: Assessments on Stove Emissions, Household Air Pollution and Personal Exposure

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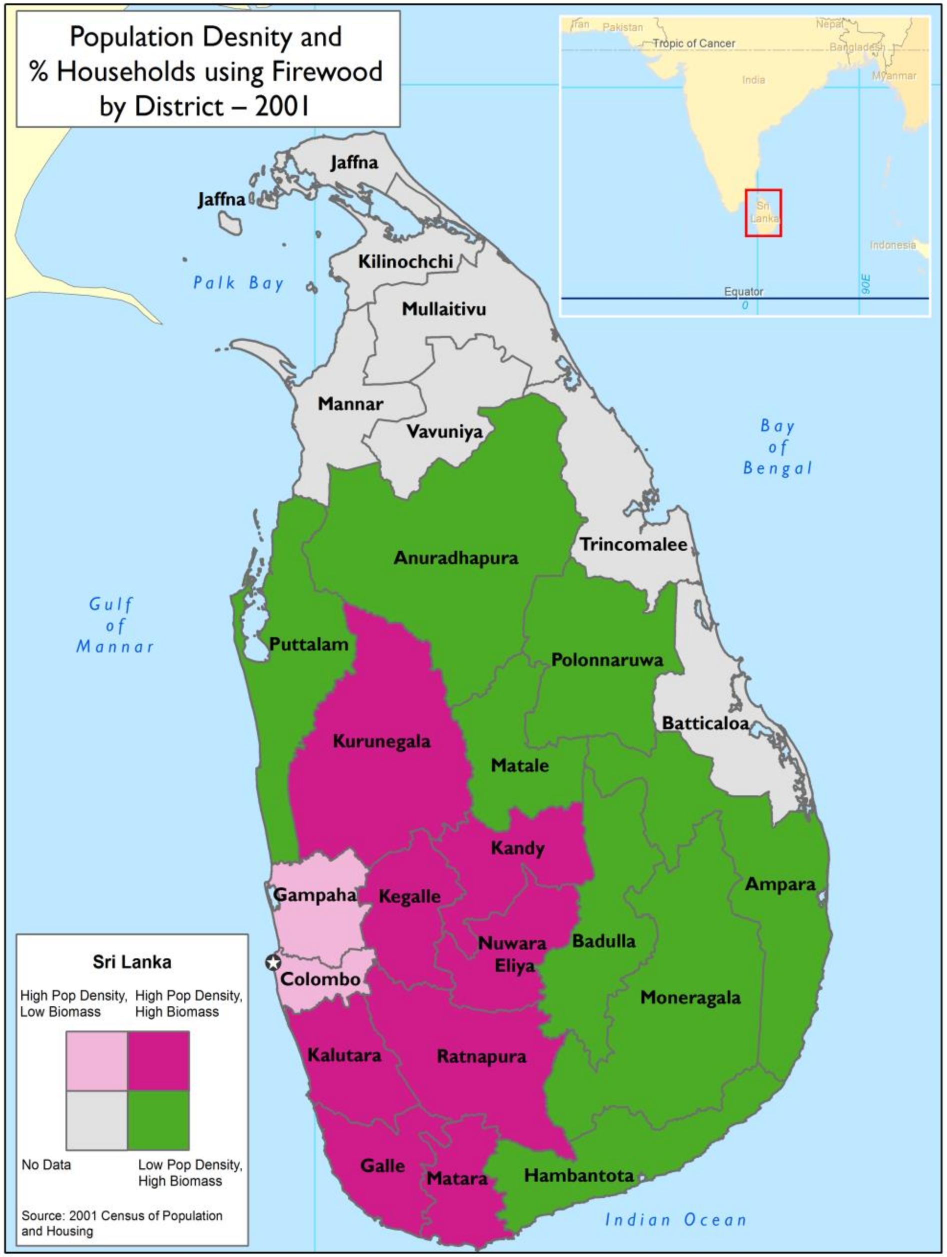
Globally, more than three billion people depend on solid fuels, particularly biomass fuels (wood, dung, crop residues), and coal, for cooking, heating, and lighting

Stoves used to burn these fuels are a leading source of household air pollution (HAP)

Millions of people die each year as a result of household air pollution; 34% are due to stroke, 26% to ischaemic heart disease, 22% to chronic obstructive pulmonary disease, 12% to childhood pneumonia and 6% to lung cancer.



Sri Lanka Case Study

In Sri Lanka, firewood is predominant biomass fuel, used by more than 78% of households

An estimated 34% of the population in urban areas used firewood as main fuel source; 84% of rural population and 96% of estate population used firewood as primary fuel

Biomass fuel is the main resource for cooking for majority of Sri Lankan households

Sri Lanka Stove Use

Rural: Biomass stove use prevalent among rural and poor populations (~85-95%)

Urban: Higher income and less biomass access contributes to propane or kerosene use, though biomass stoves used (~30-40%), even with LPG available

At-risk population: Large young population, women and children, and a sizeable aging population

HAP is a serious risk for groups who are often inside homes during biomass stoves use

Emissions

Kitchens in which firewood was used with traditional stoves reported average PM2.5 concentrations of 200 to 1,200 µg/m3 (micrograms per cubic meter)

These exposures are much higher than, the 25 µg/m3 WHO guideline for 24- hour ambient levels of PM2.5

Combustion of Biomass Fuels Produces Range of Harmful Substances

Combustion of biomass fuels for cooking produces a range of substances harmful to human health, including particulates, carbon monoxide, nitrogen oxides, sulfur oxides, formaldehyde, and polycyclic aromatic hydrocarbons, which includes such carcinogens as benzopyrene.

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Diseases Associated with HAP

Sri Lanka respiratory disease and mortality rates reflect vulnerable population exposures to HAP

Children:

- In Sri Lanka respiratory disease among leading cause of death in children 1 to 4 years of age;

- WHO reported that respiratory disease among Top 5 leading cause of neonatal death

Diseases Associated with HAP

- NCDs leading cause of mortality and DALYs in Sri Lanka

- Elderly are at increased risk for developing cataracts, heart disease, and respiratory diseases when exposed to HAP

- Increased mortality in older adults from non-communicable diseases, particularly ischemic heart disease, strokes, and diabetes

Pregnancy and Neonatal Outcomes:

- Infant mortality per 1,000 live births was 10 in urban areas, 19 in rural areas, and 29 on the estates
- Respiratory disease ranks 5th among all causes of neonatal death.
- Exposure increases risk of fetal hypoxia, reflected in low birth weight and higher risk of miscarriage.
- Estimated 22% of infants are born with low birth weight.
- Other Asian studies suggest correlation between miscarriage and wood fuel use in the home.

Diseases Associated with HAP

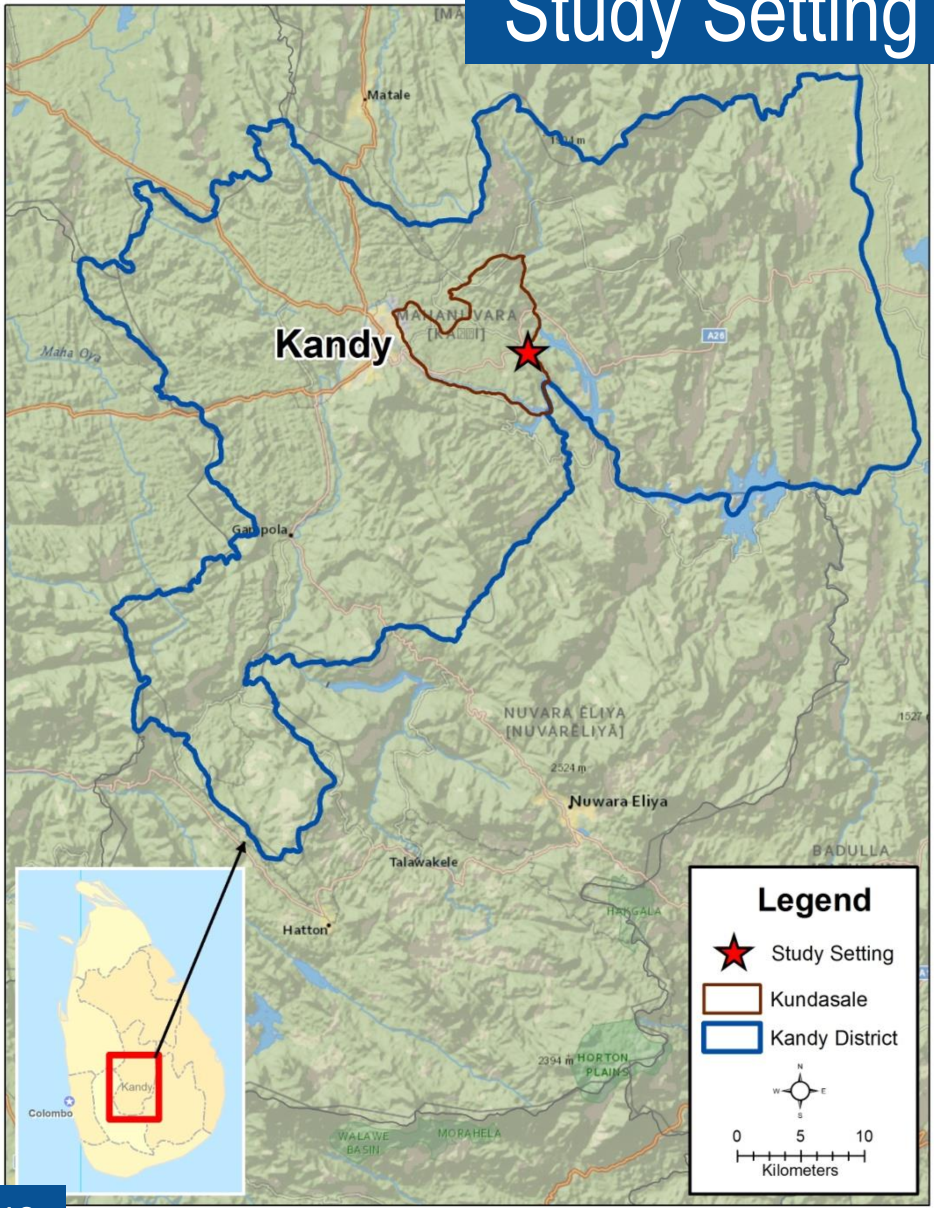
HAP also is suspected to be responsible for a range of cancers from long term exposures. The known carcinogenic emissions from combustion of solid fuels suggest that elevated cancer rates will be found among individuals exposed.

Diseases with extended latency periods have received far less epidemiologic attention in developing countries than acute diseases.

Analyzing Environmental Health Risks – 2012 Sri Lanka Exposure Study

- Sample Design
  - Cross-sectional design via a convenience sample
  - 53 households with a combination of:
    - Traditional stoves with & without a chimney
    - Anagi stoves with & without a chimney
- Screening and recruitment
  - Eligibility criteria: 18 years old or older, nonsmoking household, a traditional or Anagi stove used for cooking
- Monitoring of IAQ
  - $PM_{2.5}$ (P&I), CO, temp/humidity (I)
- Questionnaires
  - Physical location and cookstove use (time activity diary)
  - Respondent and observational surveys, health survey

Study Setting



- Kandy region, intensive biomass stove use
- Urban and rural
- Kundasale division in the Kandy District
- Rural village (Kopiwatta)
- Approximately 750 homes

Stove Types & Monitoring Setup

Anagi

Traditional

Monitoring

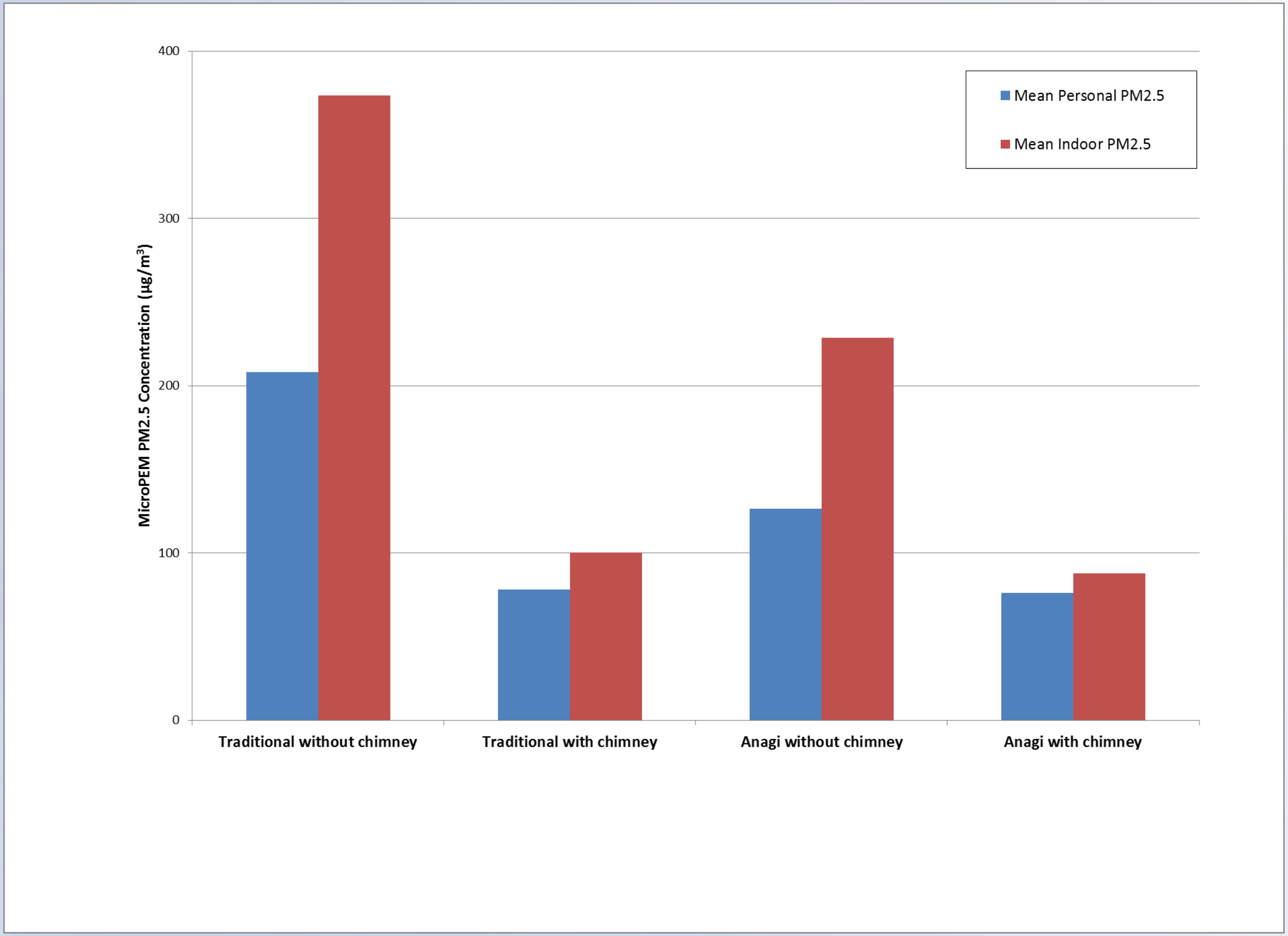
Characterizing Emissions using RTI's MicroPEM^{TM}

- MicroPEM™ personal exposure monitor used to measure real-time emissions at multiple locations in real-time
- Worn by the user for personal exposure or placed at a fixed location
- Integrated referee filter PM measurements with inlet sizing at $PM_{2.5}$ or PM_{10}
  - Enables post-analyses and identification of potential confounding data such as tobacco smoke

Assessment: Summary of Houses

House	Stove	Chimney	Avg Personal Conc. (µg/m³)	Avg Indoor Conc. (µg/m³)
1	Traditional	Yes	141.2	171.6
2	Traditional	No	94.4	112.8
3	Traditional	No	98.5	97.4
4	Anagi	Yes	43.2	46.5
5	Anagi	Yes	62.5	62.6
6	Traditional	Yes	66.7	112.4
7	Traditional	No	521.9	581.3
8	Traditional	No	215.7	417.7
9	Traditional	No	105.4	146.5
10	Traditional	Yes	58.2	47.4
11	Anagi	No	89.1	169.4
12	Anagi	Yes	157.1	170.3
13	Anagi	Yes	47.2	66.3
14	Traditional	Yes	59.8	71.8
15	Traditional	No	78.9	105.9
16	Anagi	No	119.1	160.8
17	Traditional	Yes	64.5	66.6
18	Traditional	Yes	120.8	148.0
19	Anagi	No	161.2	202.2
20	Anagi	No	151.8	115.8
21	Anagi	Yes	78.8	108.8
22	Anagi	No	114.0	272.2
23	Traditional	Yes	69.9	61.6
24	Anagi	Yes	58.9	52.1
25	Anagi	No	325.7	541.4
26	Anagi	No	89.9	141.7
27	Anagi	Yes	124.8	208.9
28	Anagi	Yes	62.4	104.7
29	Anagi	Yes	125.3	130.0
30	Traditional	No	179.8	345.5
31	Traditional	Yes	62.6	65.2
32	Anagi	Yes	no data	36.6
33	Anagi	Yes	49.0	53.6
34	Anagi	No	128.9	238.8
35	Anagi	Yes	34.5	31.9
36	Anagi	No	69.2	144.7
37	Anagi	No	no data	470.9
38	Anagi	Yes	49.1	60.0
39	Traditional	Yes	58.1	157.4
40	Anagi	Yes	146.7	152.2
41	Anagi	Yes	45.6	36.8
42	Anagi	Yes	83.2	82.8
43	Anagi	Yes	72.3	50.0
44	Traditional	No	112.0	488.8
45	Anagi	No	56.5	91.6
46	Traditional	No	298.3	502.7
47	Anagi	No	83.1	192.7
48	Anagi	Yes	45.8	59.3
49	Anagi	Yes	45.2	52.9
50	Anagi	Yes	68.2	90.9
51	Traditional	No	208.6	371.7
52	Anagi	Yes	120.2	185.6
53	Traditional	No	374.2	939.5

Stove & Chimney Combination



Exposures for Homes

The average filter data show the improved Anagi stove reduced both indoor and personal exposure by 36%, while a chimney reduced exposure by upwards of upwards of 60-70%.

Stove Type	Chimney Present in Home	Number of Homes	Mean Personal MicroPEM $PM_{2.5}$ Concentration (µg/m³)	Mean Indoor MicroPEM $PM_{2.5}$ Concentration (µg/m³)	$PM_{2.5}$ Personal-to-Indoor Ratio	Indoor CO Concentration (mg/m³)
Traditional	No	11	208.0 ± 140.2	373.6 ± 257.6	0.56	4.72 ± 3.26
Traditional	Yes	9	78.0 ± 30.8	100.2 ± 47.8	0.78	0.87 ± 0.77
Anagi	No	12	126.2 ± 73.8	228.5 ± 139.7	0.55	4.06 ± 2.79
Anagi	Yes	21	76.0 ± 37.7	87.7 ± 52.7	0.87	0.90 ± 1.08

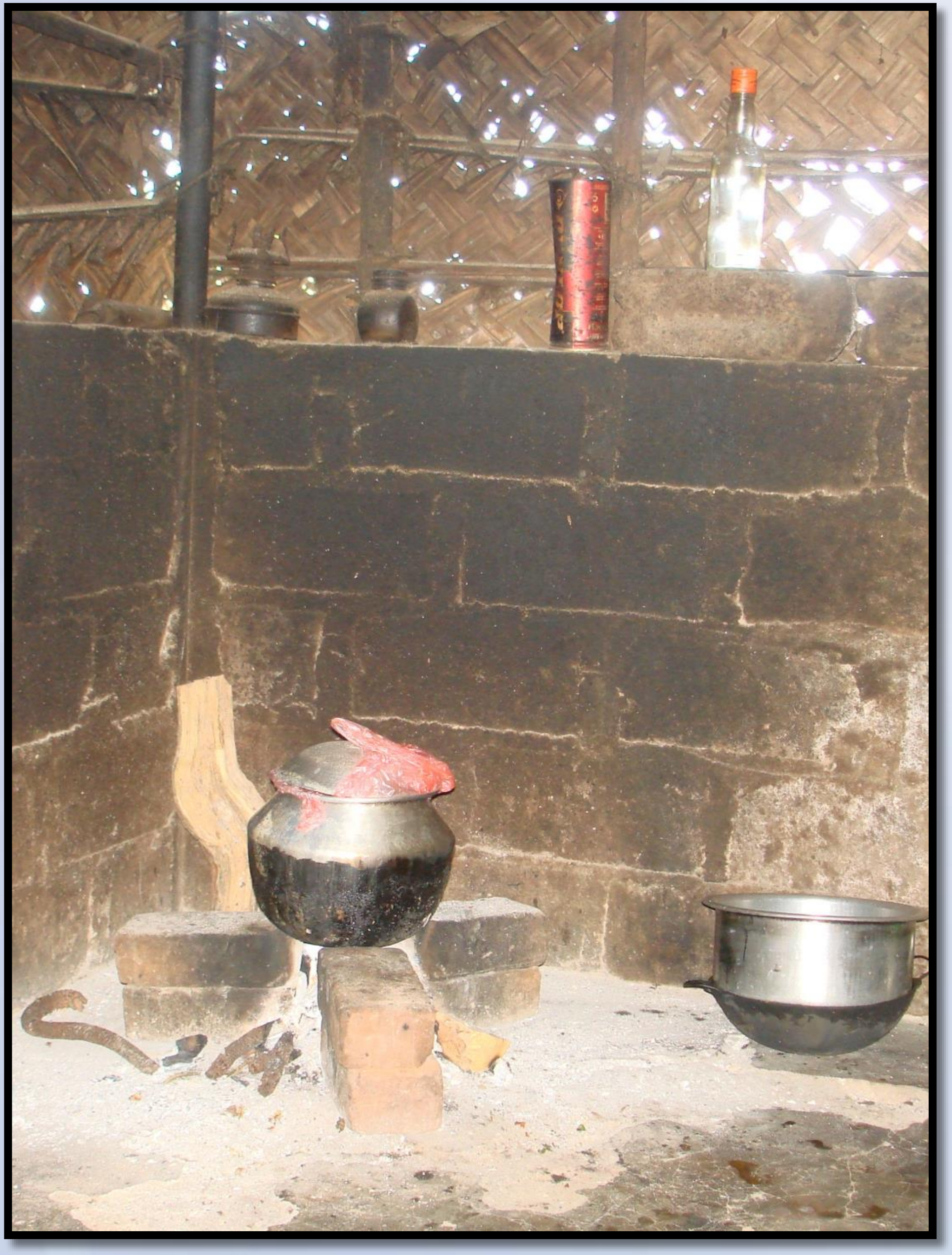
± StandardDeviation

Measuring Improvement

Stove	Chimney	$PM_{2.5}$ Reduction Personal (%)	$PM_{2.5}$ Reduction Indoor (%)	CO Reduction (%)
Anagi over Traditional	No	56.16%	38.84%	13.98%
Anagi over Traditional	Yes	2.56%	12.48%	-3.45%
Traditional w/ chimney	Yes	62.50%	73.18%	81.57%
Chimney Advantage (same stove)	Yes	39.78%	61.62%	77.83%

Study Conclusions

- Sri Lanka exposure study
  - Risks are high, based on rich data set: 98% data capture, ~5400 hours of data logged
  - New knowledge on emission levels in most prominent “improved” indigenous stove type in real household settings
  - Anagi stove is an “improved”, though not such to bring significant health improvements
  - Ventilation matters, chimneys matter more than biomass stove types



Education & Program Interventions

Perception is that ambient air pollution rather than indoor air quality causes respiratory illnesses

Education on ventilation and moving away from stove at peak times will be beneficial

Policy, standards, and HAP program education and mitigation efforts are needed

There is a lack of understanding of the health risks and consequences among both stove users and policy makers

Public Policy in Sri Lanka

HAP has attracted limited public health attention or programmatic interventions. No national action plan on HAP management.

Few HAP studies have been conducted to date.

National health, environmental, and energy policies have not adequately addressed HAP risks or widespread biomass stove use as a public priority.

Opportunity to be a leader to adopt new WHO Guidelines and bring together coalition of Ministries

Contacts

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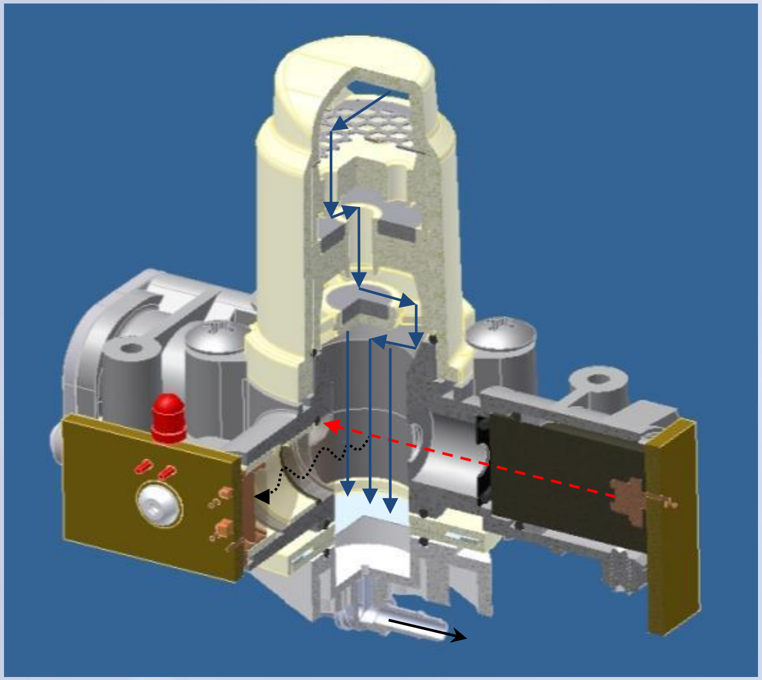
Appendix

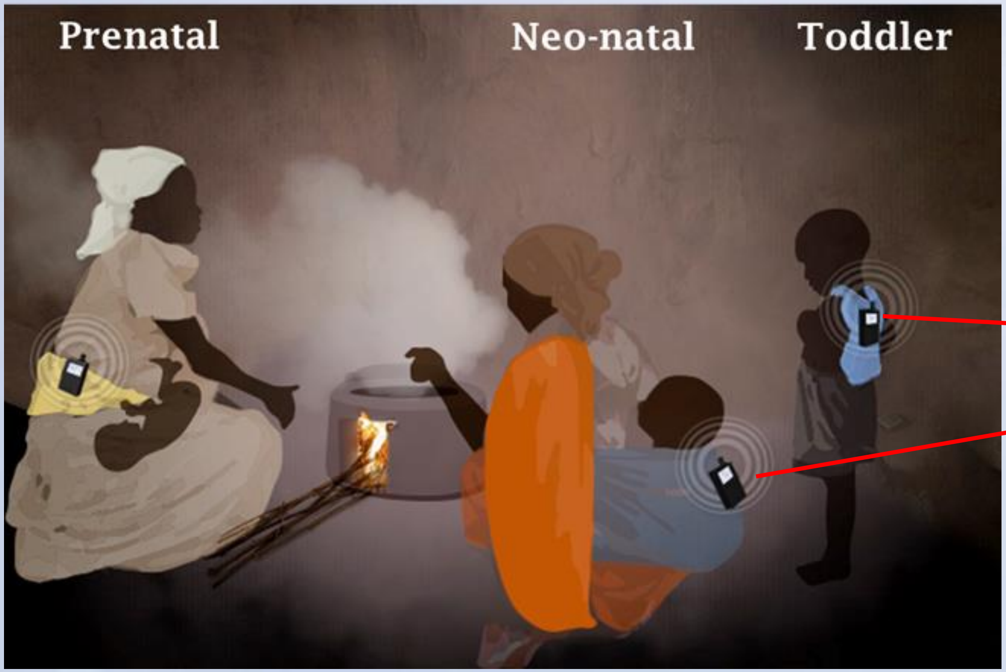
RTI MicroPEM™ Technology



- RTI MicroPEM™ measures a person’s exposure to harmful particulate matter (PM) in the air
- Light weight monitor (< 240g) that collects both real-time and integrated PM levels
- Onboard accelerometer monitors adherence to study protocol and can be used to estimate ventilation rate/inhaled dose from activity level
- Has been used in domestic and international exposure research studies
- Bringing new rigor to HAP research

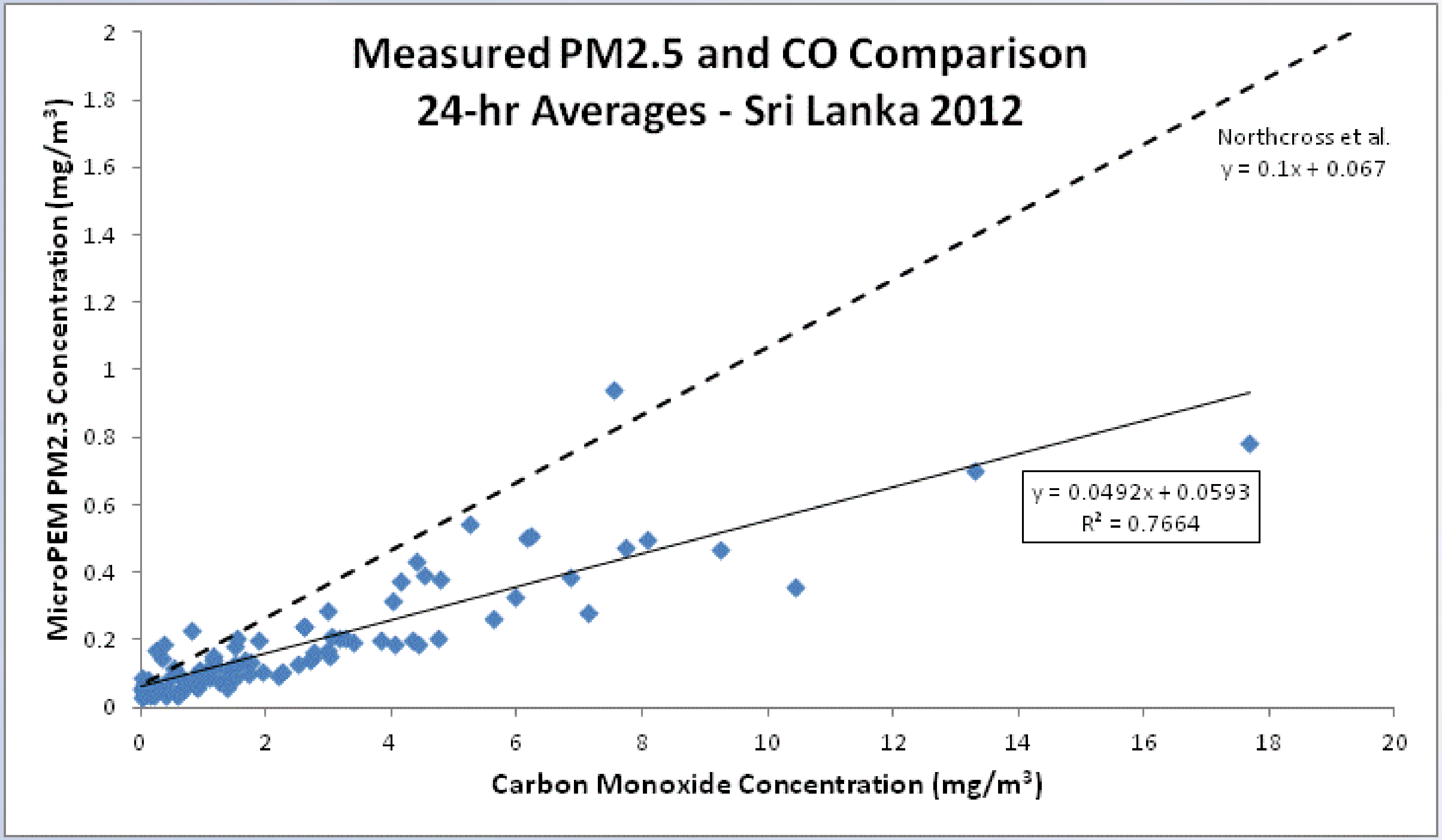
Enhanced Children's MicroPEM

- With grant from Gates Foundation making a children's version of the MicroPEM (age < 5 years) to support HAP cook stove health studies
- Enhanced Children's MicroPEM (ECM) weighs 140g (v3.2 MicroPEM 240g)
- Prototype testing is underway
- Planning field trial in 2016

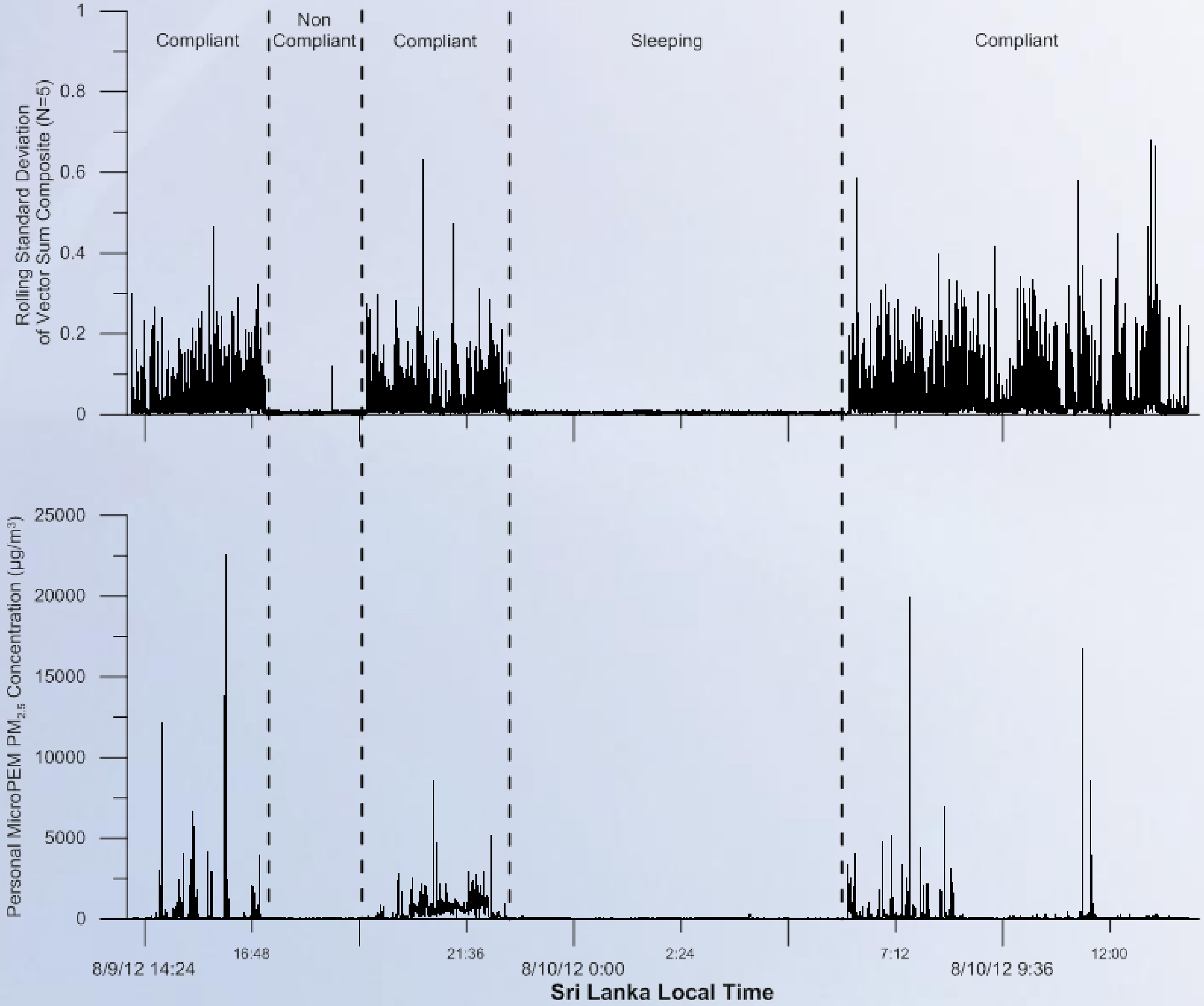


Children's MicroPEM

PM2.5 and CO Comparison

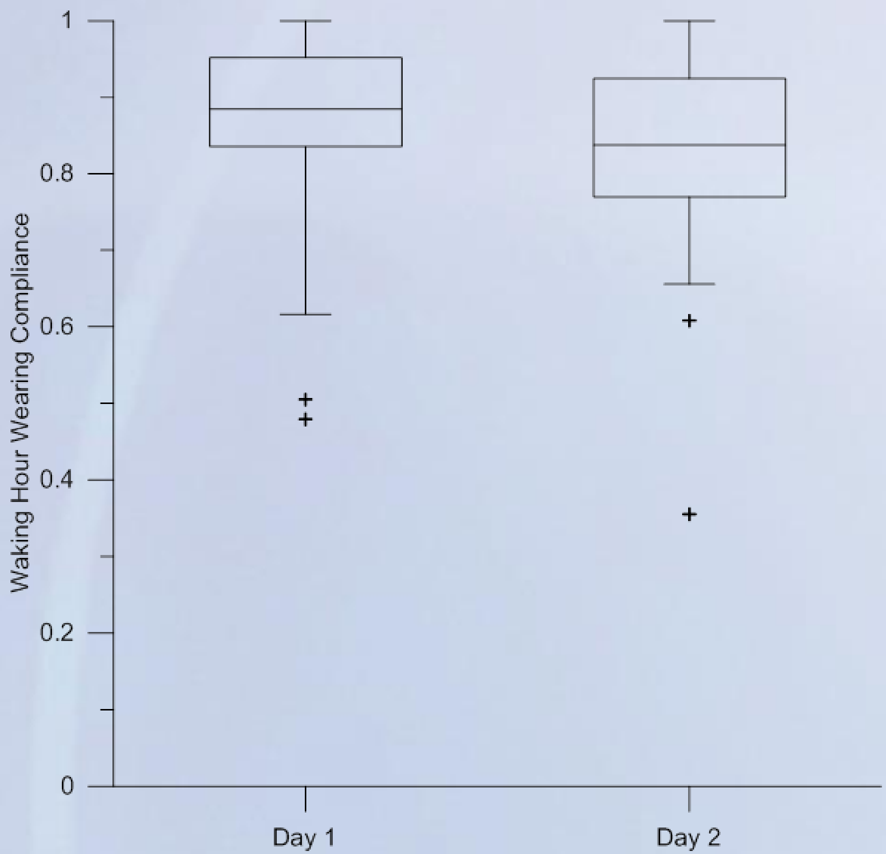


Sample Wearing Compliance – House 40



Wearing Compliance
Ends = 95th and 5th percentiles

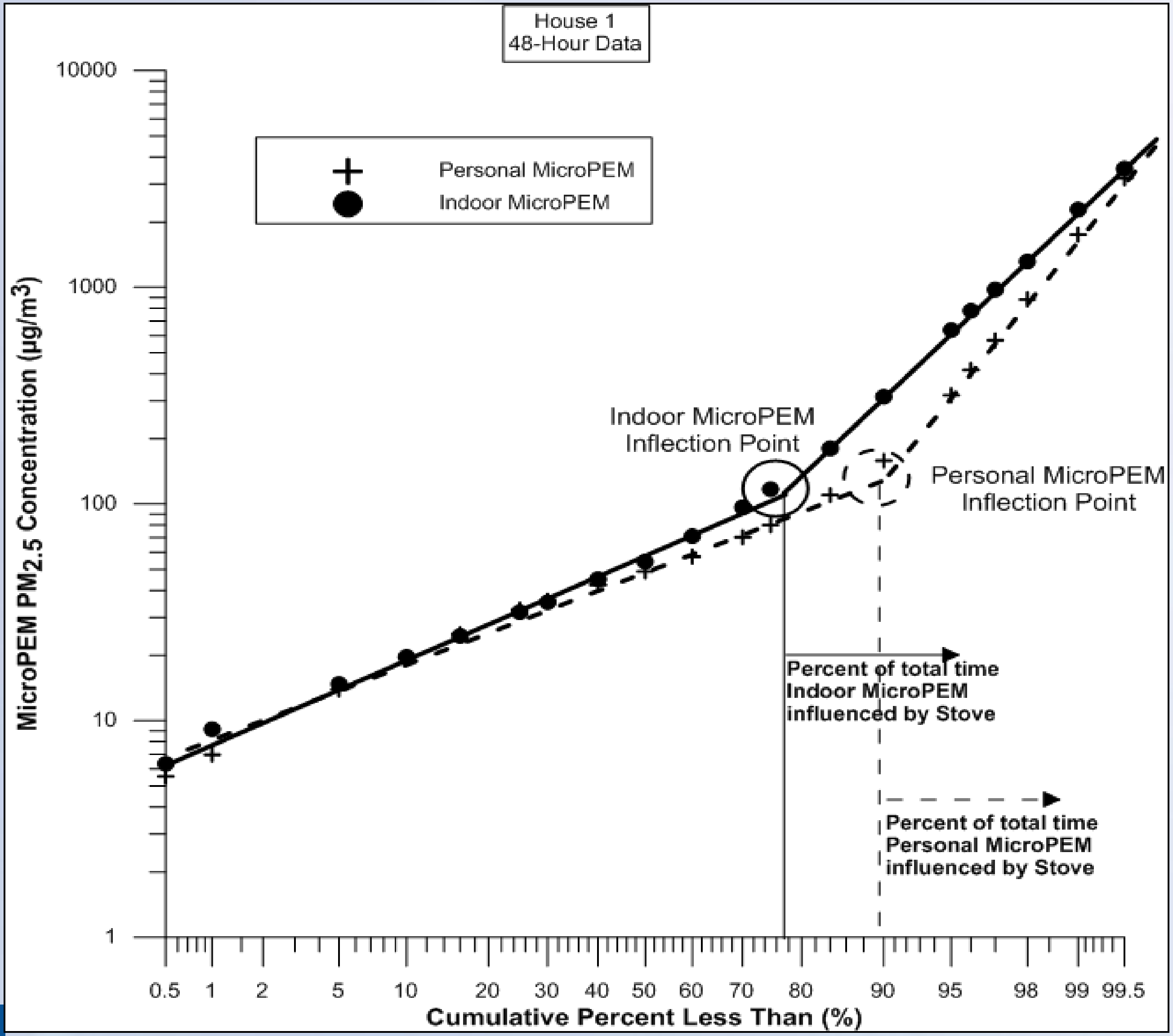
All 4 Outlier points are from 2 houses, but despite the lower compliance the cooks did wear MicroPEM while cooking



Average waking hour wearing compliance for the entire study was 85.28% (~ 14 hours/day).

This is an exceptionally high compliance value. The participants were invested in the study, which made them more apt to wear the monitors. Women tended to stay home or in the village, which made it more likely they kept the monitors on.

Innovations w/ Real-time Stove Data



This is a new way of looking at real-time cook stove data.

Innovation in Understanding Exposure

- RTI study shows new ways to view and evaluate exposure to cookstove smoke. Graphing the real-time data in log probability format shows multiple distinct slopes, which should correspond to different $PM_{2.5}$ sources. The inflection point, where the data transitions from one slope to another, should indicate the percentage of the total sample time under the influence of a particular source. Figure is an example graphic, using data from House #1
- In figure, the data to the left of the inflection point corresponds to ambient background aerosol, while data to the right of the inflection point indicates influence of smoke from the stove. Due to the location of the units, the cumulative percentage corresponding to the indoor MicroPEM inflection point is the amount of time the stove is being used, while that of the personal MicroPEM should be the amount of time the cook is exposed to smoke emissions. The difference between the two inflection points indicates the amount of time the stove is on, but the cook is not under the influence of the stove.
- This could be very important as many exposure studies us only an indoor monitor and assume this corresponds to personal exposure.