Evaluation of Acceptability and Performance of Stove Options for Reducing Household Air Pollution in Rural West Kenya

Fuyuen Yip, PhD, MPH

B. Christensen[1], K. Sircar[1], T. Pilishvili[1], J. Loo[1], D. Pennise[2], L. Naeher[3], N. Bruce[4], L. Horton[1], Michael Sage[1], Vik Kapil[1]

[1]Centers for Disease Control and Prevention, [2]Berkeley Air, [3]University of Georgia, [4]University of Liverpool

Division of Environmental Hazards and Health Effects
National Center for Environmental Health

Study Objectives

- **Exposure Assessment**: Assess 6 improved cookstoves (ICS) in their effectiveness to reduce HAP exposure
- **Acceptability**: Evaluate factors influencing adoption and use among local users

Stove Types

Stove	Design	Combustion Chamber
Ecochula	Electric fan-assisted	Ceramic
Ecozoom	Improved rocket	Ceramic
Envirofit	Improved rocket	Alloy steel
Philips	Electric fan-assisted	Ceramic
Pratki	Rocket w/ chimney	Alloy steel
RTI TECA	Rocket w/ thermal-powered fan	Brick/Clay
3 Stone (Traditional)	Stones	None


3 Stone


Ecochula


Ecozoom

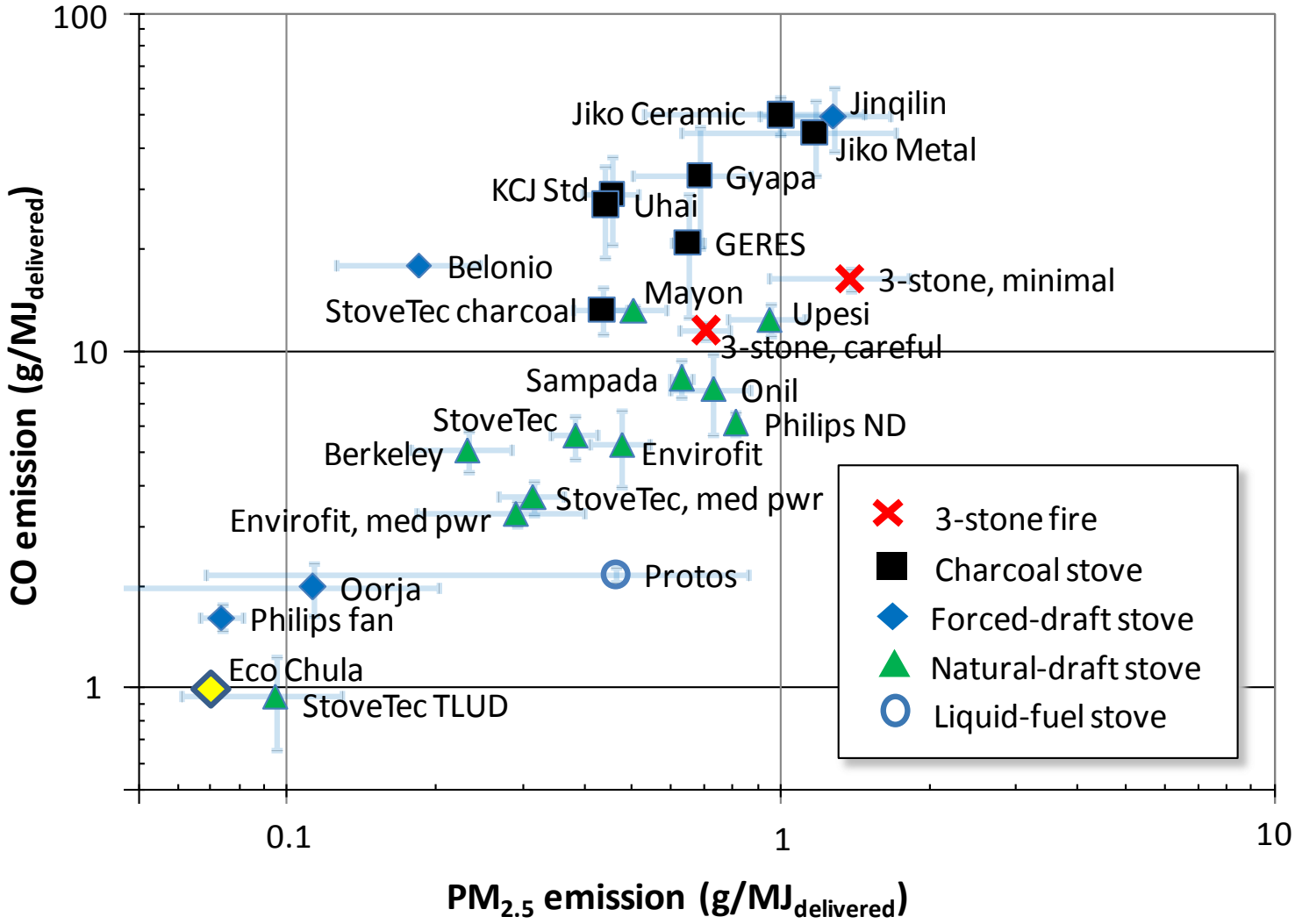

Envirofit


Philips


Pratki


RTI TECA

Emissions – Low-moisture fuel, high-power (cold start)



James Jetter et al., Environ. Sci. Technol. 2012, 46, 10827−10834

METHODS

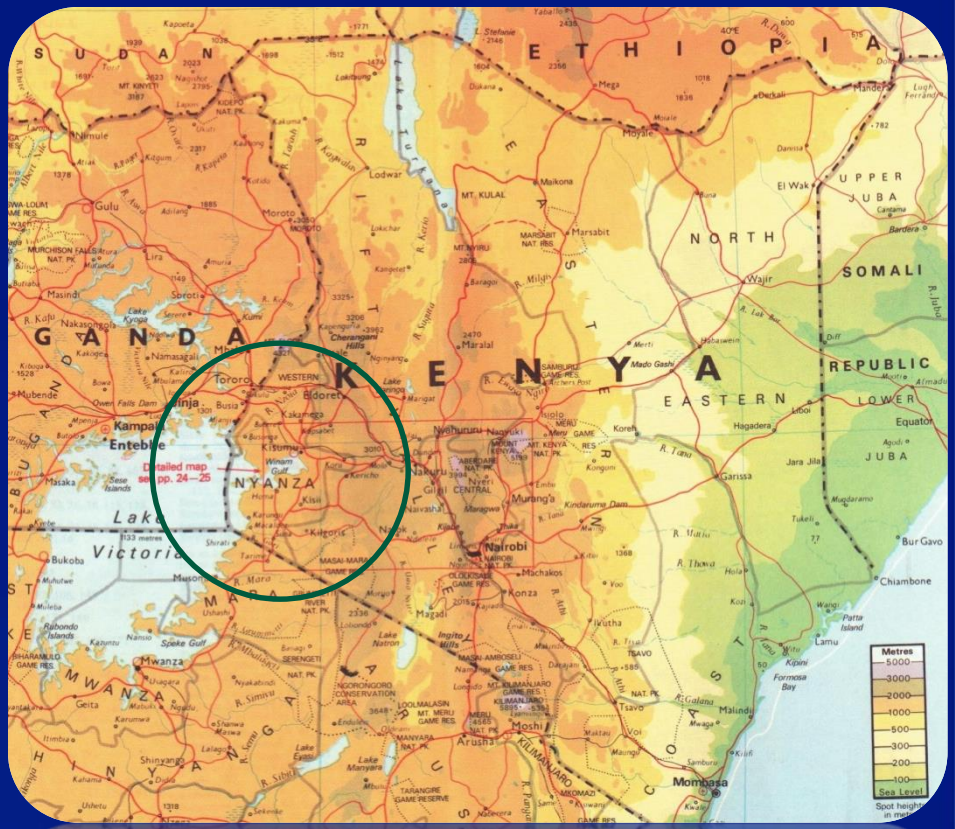
Study Location and Population

Location:

2 villages in Nyanza Province (Western Kenya)

Population:

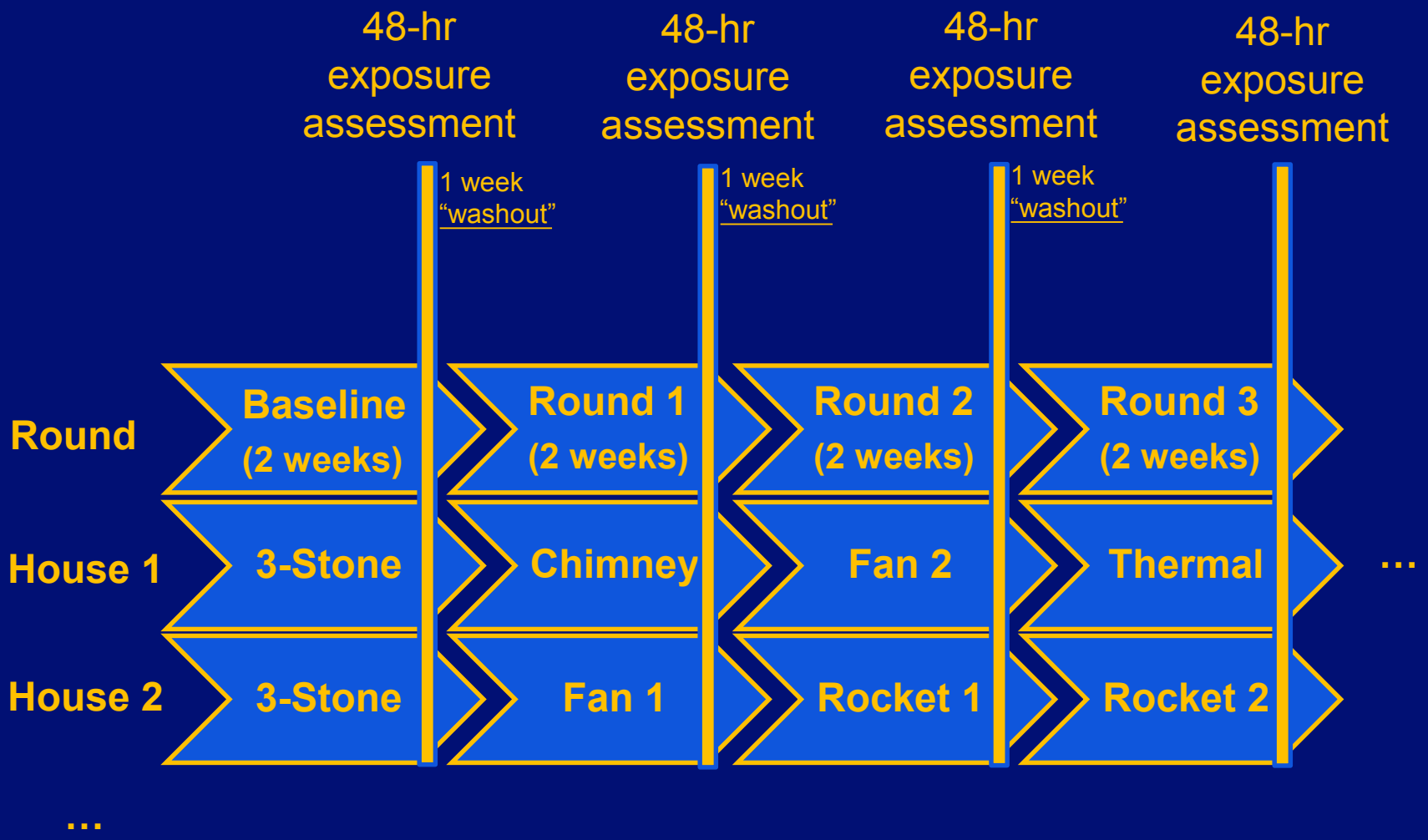
- 4.2 persons per house
- 99% cook with 3 stone fires
- 72% cook inside home



Study Design

- July 2012–February 2013
- Cross-over design
- 43 households recruited from all eligible households
- 5–6 improved stoves assigned per household

Study Design Schematic



Exposure Assessment: Indoor and Personal Air Pollution Monitoring

Location	$PM_{2.5}$	CO
Kitchen	Gravimetric (BGI Triplex cyclone, 37 mm Teflon filter)	GasBadge Pro (real-time, 1 minute intervals)
	UCB Particle and Temperature Sensor (real-time, 1 minute intervals)	
Personal	--	Mother: GasBadge Pro (real-time, 1 minute intervals)
	--	Mother and child: Draeger Color Diffusion Tubes

Exposure Assessment: Other Measurements

- Kitchen performance test
  - Fuel consumption
  - Fuel moisture
- Urinary biomarker (PAHs)
- Stove Use Monitor Systems (SUMS)
- Ambient air monitoring

Qualitative Assessment

- **Interviews**
  - Conducted at baseline and after each new stove
  - Collected information on cooking practices, fuel collection
  - Completed time-activity diary
  - Explored experience of using ICS vs. 3 stone fire
- **Focus groups**
  - Conducted after Round 4 and at end of study
  - Explored stove comparisons and issues related to promotion and scale-up

Multiple Methods for Investigating ICS Uptake

	HAP Monitoring	Time Activity Log	Survey	Qualitative Interviews	Focus Groups
Contextual Factors					
Household composition		✓	✓		
Gender roles		✓	✓	✓	✓
Socio-economic status			✓	✓	✓
Cultural and tradition		✓		✓	✓
Fuel and Technology Characteristics					
HH PM	✓				
Personal CO	✓			✓	
Stove maintenance	✓		✓	✓	✓
Biomass quality	✓	✓	✓	✓	✓
Fuel savings	✓			✓	✓
Stove characteristics				✓	✓
Smoke	✓			✓	✓
Behavioral Factors					
Stove stacking	✓	✓	✓	✓	✓
Time savings		✓	✓	✓	✓
Stove performance	✓			✓	✓
Gender roles				✓	✓
Willingness to buy				✓	✓
Satisfaction with stove			✓	✓	✓
Optimal stove use	✓	✓		✓	✓
Health Outcomes					
Symptoms			✓	✓	✓

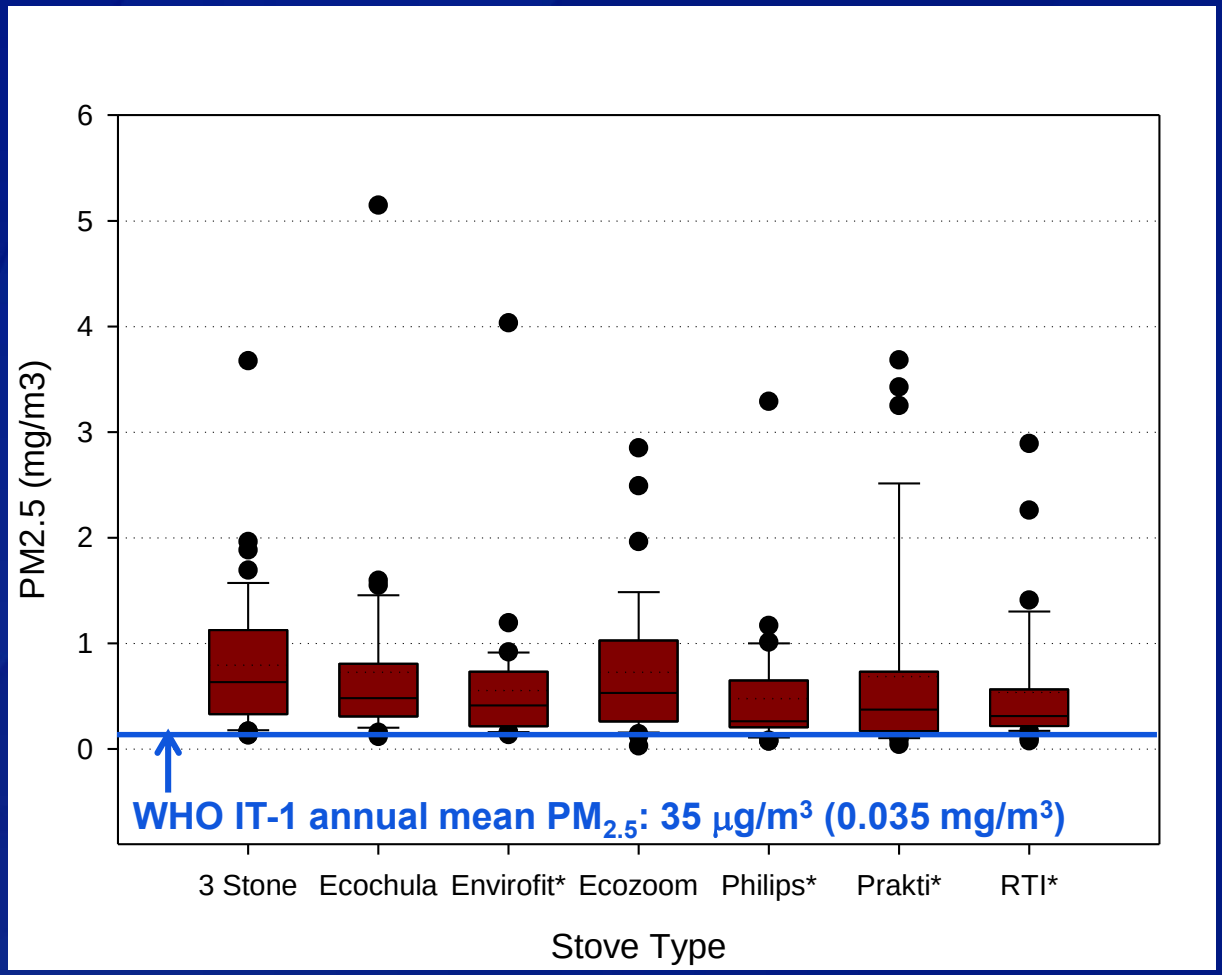
CDC ATSDR

Data Analysis

- Descriptive statistics
- Pairwise t-tests to assess differences in kitchen concentrations between ICS and 3 stone fire
- Median percent reduction for the 6 ICS compared to 3 stone fire in the kitchen

PRELIMINARY RESULTS

Gravimetric $PM_{2.5}$ Concentration (48-hr) in Kitchen, by Stove Type

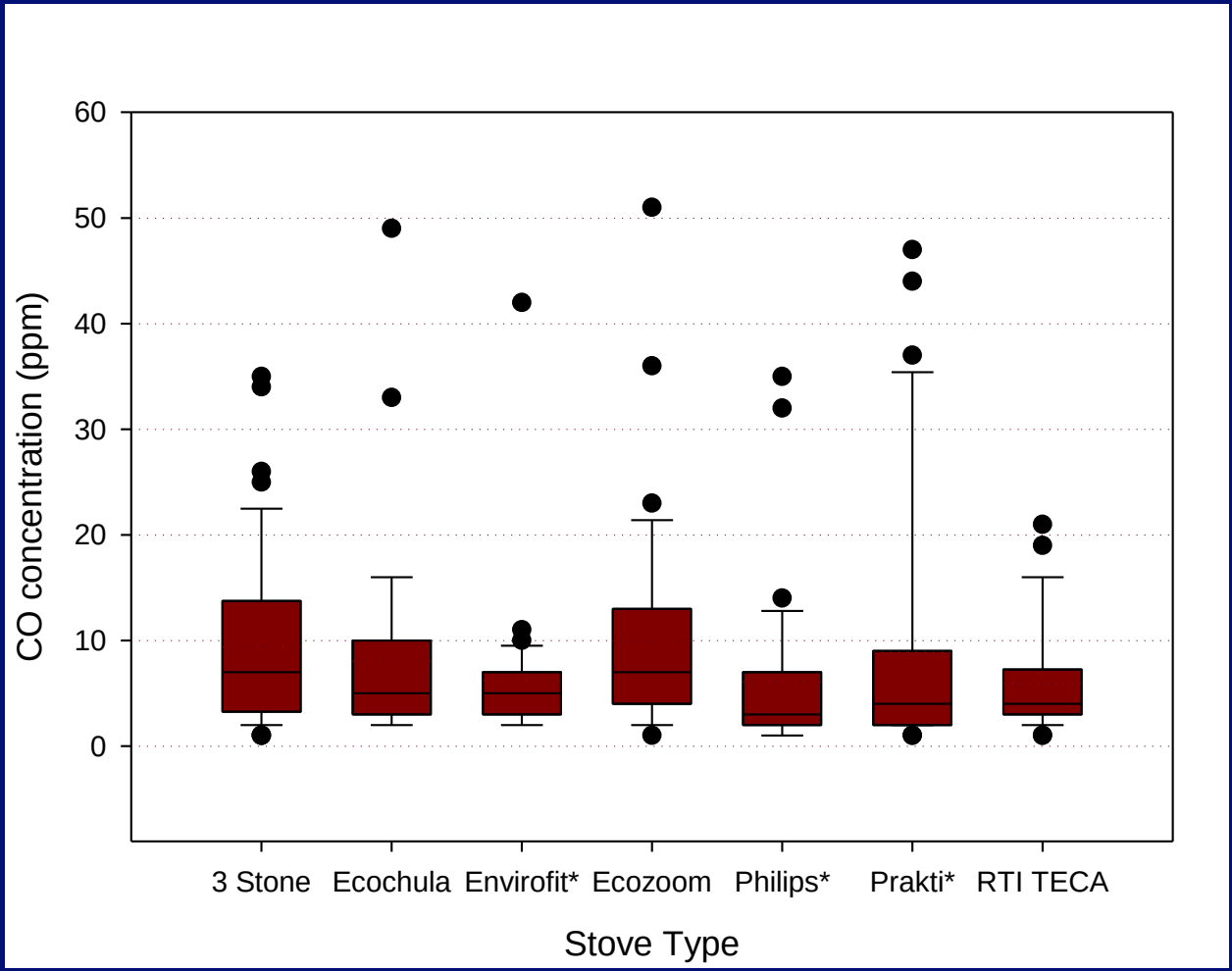


* p<0.05

Median Percent Reduction for $PM_{2.5}$: ICS vs. 3 Stone Fire, by Stove Type

Stove Type	N	Median percent reduction	95% CI
3-Stone	45	ref	ref
Ecochula	36	25.5	-7.0, 42.2
Ecozoom	37	24.4	-1.7, 46.5
Envirofit	35	43.2	16.6, 55.1
Philips	36	48.1	35.0, 60.7
Prakti	39	38.5	24.9, 61.9
RTI TECA	35	44.8	8.1, 53.8

Carbon Monoxide Concentration (48-hr) in Kitchen, by Stove Type

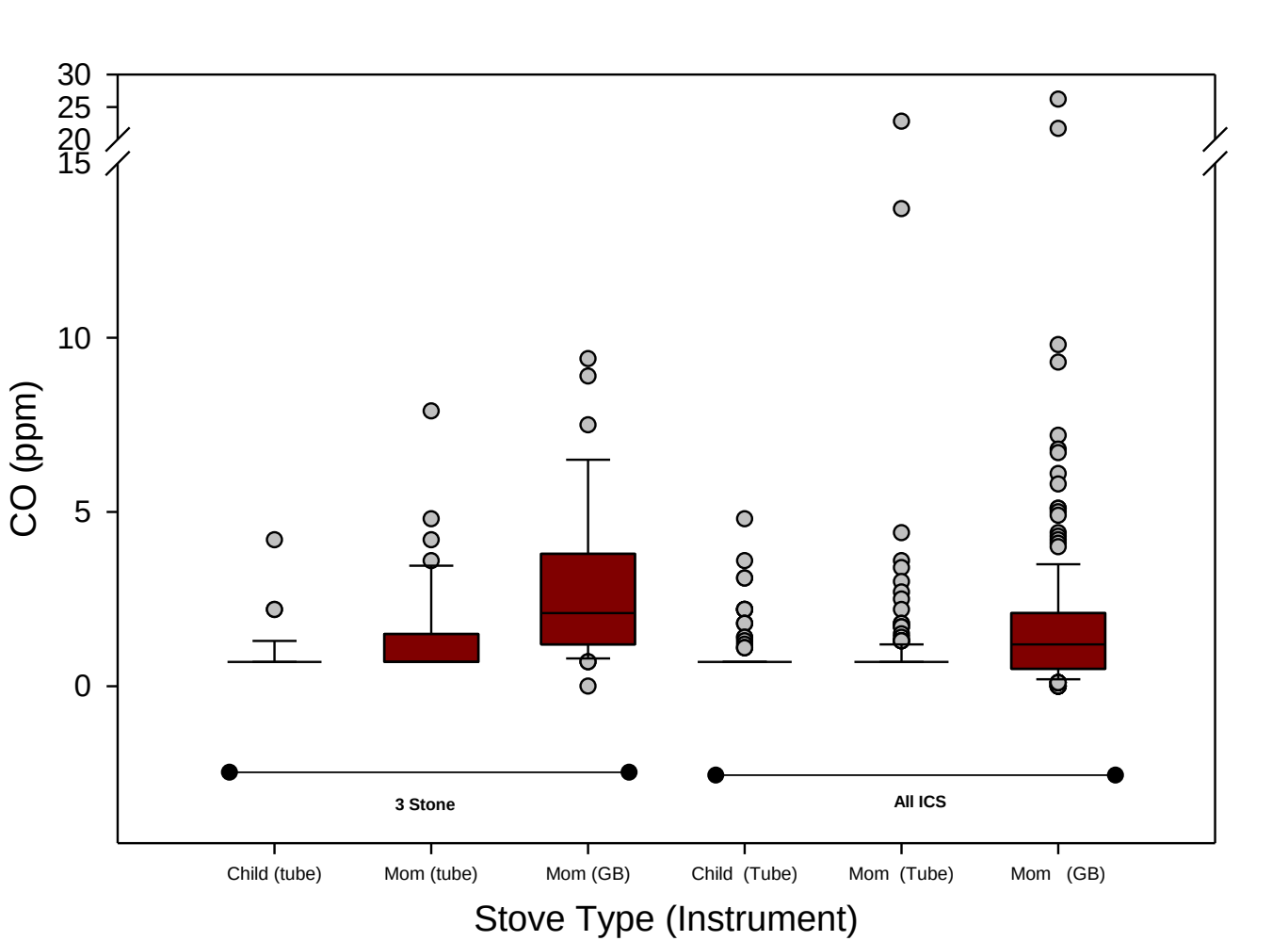


* p<0.05

Median Percent Reduction for CO: ICS vs. 3 Stone Fire, by Stove Type

Stove Type	N	Median percent reduction	95% CI
3-Stone	44	ref	ref
Ecochula	35	18.8	-5.4, 54.8
Ecozoom	37	12.6	-10.9, 30.7
Envirofit	34	34.5	14.2, 52.9
Philips	35	53.1	5.5, 62.2
Prakti	38	37.3	0.57, 55.7
RTI TECA	34	22.0	9.38, 57.5

Personal CO Concentrations: Mother and Child



Summary: Exposure Assessment

- The mean kitchen $PM_{2.5}$ concentration for the 3 stone fire >20 times greater than the WHO IT-1.
- Improved stoves emitted less $PM_{2.5}$ and CO but still high and a lot of variability observed.
- All ICS showed median reductions for $PM_{2.5}$ and CO in comparison to 3 stone fire.
- Observed reduction in personal CO exposures between the ICS and 3 stone fire when measured with GasBadge.

Conclusions: Exposure Assessment

Multiple factors likely influence the observed variability in $PM_{2.5}$ and CO concentrations including:

- use of more than one stove for cooking (stove “stacking”)
- use of kerosene lamps
- type and quality of fuel used (e.g., wood vs. dung, fuel moisture content)

Qualitative Findings

- **Favored improved stoves**
- **Felt health benefits considerable**
- **Reported reasons for stove stacking**
  - Difficult to light
  - Slow cooking speeds
  - Hard to use (pot size)
- **Preferred stove characteristics**
  - Lower fuel consumption
  - Less visible smoke
  - Rapid heating
- **Identified issues affecting promotion and scale-up**

Other Qualitative Observations

- Women expressed and behaved with a real interest in exploring new technology to promote clean and safe cooking.
- New stoves reduced emissions (4 of 6 statistically significantly).
- However emissions from all stoves tested remained above levels that would be needed to realize the maximum public health benefit.
- The story is more than the stove itself: it is the stove design and performance, women's needs and use, other sources of household air pollution, fuel moisture content, ventilation, and availability/cost.

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Thank you

For more information please contact Centers for Disease Control and Prevention
1600 Clifton Road NE, Atlanta, GA 30333
Telephone, 1-800-CDC-INFO (232-4636)/TTY: 1-888-232-6348
E-mail: cdcinfo@cdc.gov Web: www.cdc.gov

◊The stoves used in this study do not represent an endorsement by the Centers for Disease Control and Prevention.

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Kerosene Lamp Summary

- Simple wick lamp contributes to $PM_{2.5}$ concentrations but not CO
- Hurricane lamp does not significantly contribute meaningfully to $PM_{2.5}$ or CO concentrations
- Unmeasured behavioral mechanisms could further modify the potential importance of the simple wick lamps on $PM_{2.5}$ exposure and area concentrations
- $PM_{2.5}$ values reported here are not filter adjusted; thus values presented here cannot be interpreted as absolute