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A Mixed Methods Approach to Assessing Indoor Air Pollution Among Women in Addis Ababa, Ethiopia

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Bachelor of Arts

Gettysburg College

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An abstract of
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Abstract

A Mixed Methods Approach to Assessing Indoor Air Pollution Among Women in Addis Ababa, Ethiopia

By Megan Graham

Background: The incomplete combustion of burning biomass fuels, such as firewood and dung, results in high levels of indoor air pollution and over 2 million deaths per year worldwide. The women of Shero-Meda subcity on the outskirts of Addis Ababa Ethiopia cook with firewood collected from the nearby Entoto Mountain and are exposed to high levels of indoor air pollution.

Objective: The research examines particulate matter and carbon monoxide levels in the homes of women living in Shero-Meda subcity, and combines these results with interviews of the women to explore their experience with firewood as their primary fuel.

Methods: Eighty four households in Shero-Meda were monitored for particulate matter and carbon monoxide for a 24 hour period. In addition, 5 in-depth interviews and 4 focus group discussions were conducted in the community discussing fuel use, fuel preference, economics and social empowerment.

Results: The 24 hour particulate matter levels in the kitchens ranged from 135 µg per m^3 to 12,737 µg per m^3 with an average of 1580 µg per m^3. All households exceeded the United States Environmental Protection Agency (USEPA) standard of 35 µg per m^3 in 24 hour time period. The 8 hour carbon monoxide averages among households ranged between 0.66 ppm and 69 ppms with an average of 16.08. Twenty-six households exceeded the USEPA 8 hour average of 9ppm. The maximum temperature recorded during cooking and kitchen volumes were seen to have significant effects on CO levels. In-depth interviews and focus group discussions revealed the economic hardship that binds women to using firewood for cooking, and the desire to utilize a cleaner fuel for cooking.

Discussion: Results provided evidence that smaller kitchen volumes had significantly higher levels of carbon monoxide. Research provides critical evidence that indoor air pollution is a major health hazard in Addis Ababa. In addition, conversations with women revealed that they are unhappy using firewood for cooking, and with increased income would prefer to use kerosene or even electricity. Improved cook stoves would reduce indoor air pollution, halt major deforestation problems in Ethiopia, allocate time for women to participate in the commercial market, and reduce the burden of disease among women and children.

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Chapter 1: Introduction

Indoor air pollution (IAP) caused by the burning of biomass fuels is a major worldwide health concern (Figure 1). Biomass fuels used for cooking include dung, wood, agricultural residues, and charcoal (Bruce, McCracken et al. 2004). The burning of such biomass fuels produces harmful toxins that may affect the health of both those who are cooking and others in the surrounding area. The smoke frequently contains particles and toxic substances such as carbon monoxide, nitrogen, sulfur, benzene, formaldehyde. (Bruce, McCracken et al. 2004). These dangerous particles and chemicals emitted from the smoke increase the risk of respiratory tract infections, asthma, Chronic Obstructive Pulmonary Disease (COPD), cardiac events, strokes, eye disease, tuberculosis, and various forms of cancer (Bruce 2008). Of all the particulate matter omitted, 75% of the global particulate matter is released in developing nations (Figure 2).

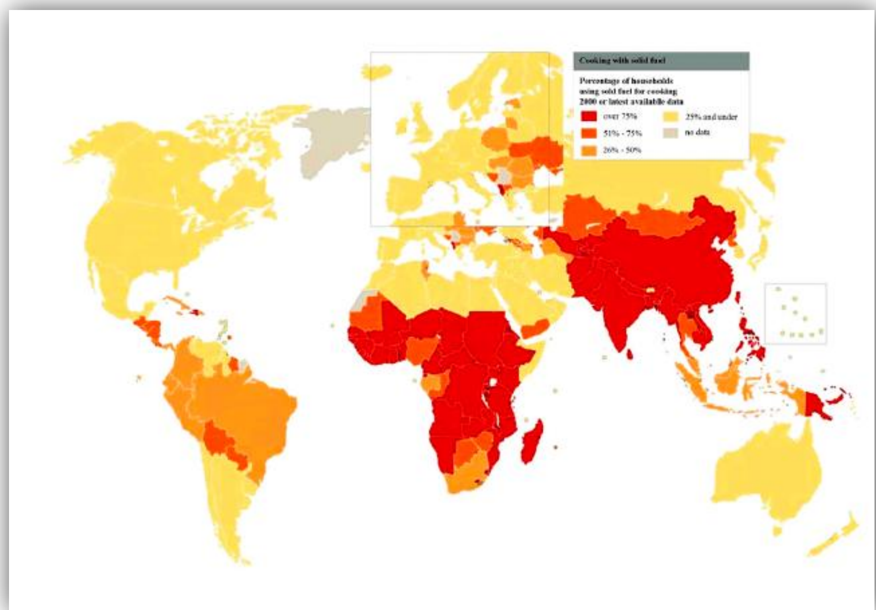

Figure 1: Worldwide Use of Biomass Fuels (Torres-Duque, Maldonado et al. 2008)

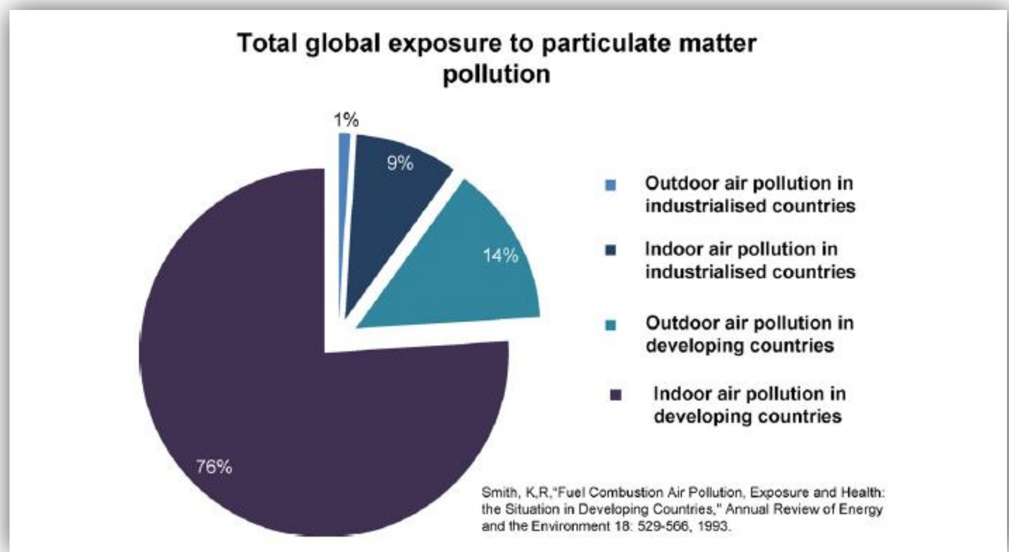

Figure 2: Pie chart demonstrating the total global exposure to all forms of particulate matter. It can be seen that indoor air pollution accounts for the majority of air pollution in developing countries.(Fullerton, Bruce et al. 2008)

Two billion four hundred million households (50% in urban areas and 90% in rural areas) rely on biomass fuels for cooking and heating their homes (Bruce 2008). The World Health Organization (WHO) estimates that the burden of disease from burning biomass fuels results in 1.6 million deaths per year and 38.5 / 1,000 DALYs per year (Torres-Duque, Maldonado et al. 2008).

Evidence reported throughout this thesis details the negative health impact of indoor biomass smoke exposure in Ethiopia during 2010. The study conducted in Shero-Meda, a sub city of Addis Ababa, the capital of Ethiopia, seeks to provide evidence of ill-health effects burning firewood for cooking daily meals. The study in Shero-Meda is one of the first biomass burning studies conducted in the urban Sub-Saharan African setting. The neighborhood where the research was conducted is situated to the north of the city, just beyond the United States Embassy and is home to the famous Shero-Meda craft market.

Problem Statement

Although much of urban Addis Ababa, Ethiopia is experiencing economic growth and prosperity, many women in the city still face damaging health effects of indoor air pollution from cooking with firewood. The urban poor are at the bottom of the energy ladder and due to lack of economic power spend much of their time cooking over a three stone fire. Not only do the women living in the slums of Shero-Meda sub city Addis Ababa face the physical burden of collecting their own firewood, they face social stigma and lifelong health effects of biomass burning for themselves and their children.

While there is a large body of literature on the burden of biomass air pollution in rural areas, there is a lack of knowledge about the hardships and physical burden of cooking with firewood in the urban African setting. Knowledge about where the community obtains cooking fuels, access the resources, utilization and time commitment to everyday cooking, and impact on health are needed to document the burden of disease and develop evidence that can be used to develop intervention strategies. Only if the data are utilized properly will this knowledge promote the understanding of biomass burning in the urban setting and provide the evidence required for improved stoves and fuels for the poor neighborhoods in Addis Ababa as well as other African cities.

Purpose Statement

The research in Shero-Meda sub city monitored carbon monoxide and particulate matter ($PM_{2.5}$) levels in households for a 24 hour period. Household selection criteria included enclosed kitchens separate from their houses which cooked with wood and met specified inclusion criteria (Table 1).

Table 1: Criteria for Indoor Air Pollution Monitoring

Inclusion Criteria
1. Women who live in Shero Meda Sub-City
2. Kitchen is a separate structure from household (sleeping and living area)
3. Kitchen is enclosed (4 walls and a roof)
4. Firewood is main fuel
5. Provided verbal consent to have kitchen activities monitored for 24 hours
Exclusion Criteria
1. Cook smokes cigarettes

Women of selected houses reported barriers to fuel, social stigma, and daily cooking procedures. Together the quantitative and qualitative data paint a picture of the levels of indoor air pollution among urban residents using firewood and promotes action to assess intervention strategies of improved stoves and alternative fuels.

Research Hypothesis

1. Do households in Shero-Meda cooking with firewood experience levels of indoor air pollution higher than Environmental Protection Agency (EPA) standards?
2. Among women cooking with firewood in Addis Ababa, do ventilation factors such as windows and kitchen size contribute to elevated levels of particulate matter and carbon monoxide?

1. Null Hypothesis: Households in Addis Ababa who cook with firewood experience levels of indoor air pollution less than EPA standards
2. Null Hypothesis: Kitchen structure and ventilation (i.e. windows) will be insignificant in extreme indoor air pollution values.

Significance Statement

Gaining insight into the quantitative carbon monoxide and particulate matter levels in the households in Shero-Meda will provide public health professionals and environmentalists with knowledge about the true levels of IAP in the urban setting. The combination of the indoor air pollution levels and reports from the women themselves will document the severity of the fuel crises and exposure to air pollution women cooking with wood within Addis Ababa. Currently, Ethiopia has ceased importing ethanol fuel that can be used for cooking. Demonstrating the need and a market for a cleaner burning cooking fuel such as ethanol in the city of Addis Ababa will provide the government with an incentive to adapt and create accessible markets to improved cooking stoves and fuels.

Chapter 2: Comprehensive Review of Literature

Previous research conducted on indoor air pollution in the developing world is comprised primarily of small scale studies due to the financial burden and methodological rigor needed to conduct large studies. Most of the research is conducted in the rural areas of developing countries; there is little knowledge surrounding the burning of biomass fuels in the urban setting. Indoor air pollution quantitative studies have proven that biomass cooking is harmful to both the health of women and small children less than 5 years of age. Studies have shown that harmful particulate matter and carbon monoxide omitted during cooking are correlated with high levels of disease among adults including COPD, lung cancer, and tuberculosis; young children to have increased rates of acute lower respiratory tract infections (ALRIs). Studies on the reduction of this burden of disease have shown that both improved stoves, fuels and ventilation in the kitchen can reduce the health effects of harmful indoor air pollution (Bruce, McCracken et al. 2004).

Measuring Particulate Matter and Indoor Air Pollution in Developing Countries

In epidemiologic studies, biomass fuels and the health impacts on those utilizing the fuels to cook or heat their homes are measured primarily in terms of particulate matter and carbon monoxide levels. Particulate matter is thought to be the best indicator of the health impacts from inefficient combustion (Naeher, Brauer et al. 2007). Particulate matter is classified by the size of the particulate, those particles less than 10 μgs in aerodynamic diameter and particles less than 2.5 μgs (Bruce, 2008). The United States Environmental Protection Agency has set standards for the amount of particulate exposure that is healthy. Within a 24 hour period it is recommended that PM_{10} exposure be less than 50μg/m^3 and $PM_{2.5}$ exposure be less than 35μg/m^3 (Table 2).

Particulates from wood smoke, generally smaller than 1μm,, are deposited in the peripheral airways, and penetrate the mucocillary system; such exposure is dangerous to the health of women and small children (Naeher, Brauer et al. 2007). Mean carbon monoxide (CO) levels in a 24 hour period can range from 2-50ppm, but can reach up to 500ppm during cooking. The EPA states that CO 8 hour average should not reach above 9ppm. Epidemiologic studies often face challenges in monitoring IAP due to the spatial distribution of the household and ventilation characteristics of the kitchen (Torres-Duque, Maldonado et al. 2008). Although monitoring households using biomass fuels is difficult, there are several studies in developing nations that have utilized methods to monitor indoor air pollution. Results support the evidence that biomass fuels are dangerous and harmful to the health of women and children.

Table 2: EPA Standards for $PM_{2.5}$ and CO with Levels Seen in Previous Studies

Pollutant	**EPA Guidelines**		**Range of Ambient Levels in LDC Studies for Simple Stoves**
	Period	*Level*	
Particulate Matter $PM_{2.5}$	24-hour	35 µg/m3	300-3,000
	During stove use	N/A	300-30,000
Carbon Monoxide (CO in ppm)	8-hour	9 ppm	2-50 (24-hour)
	During stove use	N/A	10-500

A study conducted in Northeastern China examined particulate matter levels in biomass burning rural households compared to non biomass burning urban households (Jiang and Bell 2008). A total of 3 rural and 3 urban households were surveyed and particulate matter PM_{10} and personal monitors for $PM_{2.5}$ were utilized for 10 participants. Researchers also recorded time-activity diaries depicting the participant's activities and locations throughout the day. The stationary PM_{10} monitors depicted higher levels of particulate matter in rural kitchens versus urban kitchens, as well as levels that increased by 6.1 times during cooking periods (Table 3). With rural cooks spending 2.8-3.6 times more time than urban cooks (2.5 hours), $PM_{2.5}$ personal monitors showed higher levels of particulates in rural cooks. The study provided evidence that biomass burning for cooking contributes significantly more particulate matter and indoor air pollution than non bio-mass burning methods (Jiang and Bell 2008).

Table 3: PM_{10} Levels in Jiang and Bell study, showing both urban and rural households and stratified by cooking and non cooking periods

	Total Study Period		Cooking Time		Non Cooking Times	
Household Type	No of Hours	PM_{10} (mean±SD)	No. of Hours	PM_{10} (mean±SD)	No. of Hours	PM_{10} (mean±SD)
Rural	190	100.6 ± 203.1	76	202.1 ± 293.6	114	33.01 ± 15.31
Urban	144	61.34 ± 111.8	29	67.00 ± 32.58	115	59.40 ± 123.8

During April 2008 a study in Malawi sampled 31 urban and 31 rural residences to examine indoor air quality over a 24 hour period. Households in the urban areas primarily used charcoal for cooking, while household in the rural areas used firewood. The households were monitored for both particulate matter at the $PM_{2.5}$ level as well as carbon monoxide. Results demonstrated that the levels of particulate matter were significantly higher than standards and 80% of the households had particulate matter levels 4 times greater than the standard levels of 25µg/m^3. Mean levels of particulates in the air in a 24 hour period were 204µg/m^3 (Table 4). Carbon monoxide levels were significantly higher in urban and rural households and averaged 6.1 ppm and 1.87 ppm respectively ($p=<0.001$). The increased CO concentrations were seen to be due to the use of charcoal in the urban households compared to the firewood used by rural households. The study showed that overall both urban and rural households in Malawi have levels of indoor air pollution that are significantly higher than WHO standards (Fullerton, Semple et al. 2009).

Table 4: Concentrations of $PM_{2.5}$ and CO

Households	Pollutant	Average	Range	Median	SD
N (47)	**PM (µg/m3)**	204	1-9000	80	381
N (48)	**CO (ppm)**	4.08	0.2-24.6	1.8	5.36

Cooking with Biomass Fuels and Health Impacts

The health burden associated with indoor air pollution and burning of biomass fuels is responsible for 2.6% of the global burden of disease; the health impacts of such fuels are focused primarily on COPD in adults and ALRIs in children less than 5 years of age (Torres-Duque, Maldonado et al. 2008). Of the premature deaths due to cooking with biomass fuels, 59% of these deaths are from ALRIs occurring in under-five children (78% of the DALYs). ALRIs are the 1st cause of under-five mortality around the world, and cause 4 million deaths a year. Torres-Duque and Maldonado et al. examined eight biomass burning studies and saw a significant relationship between burning biomass fuels and ALRIs incidence with an overall estimated risk of 2.3 (95% CI 1.9-2.7) for children under 5 years of age. For children younger than 2, the risk of contracting ALRIs from biomass fuels was 2.5 (no 95% confidence interval reported).

COPD occurs among adults and is one of the leading causes of the global burden of disease among those older than 40. The examination of eight studies showed that women exposed to indoor air pollution from biomass burning stoves were 3.2 times more likely to have COPD than men who most likely didn't participate in the cooking process (95% CI 2.3-4.8). Cooking with a biomass stove for 10 or more years was seen to be a risk factor for COPD after adjusting for age, sex, smoking, education, history of TB and exposure to particulates in the work setting (OR 1.5, 95% CI 1.36-2.36) (Torres-Duque, Maldonado et al. 2008).

China

Studies examining the health effects of indoor air pollution have been conducted in several developing countries. A 2003 study in Southern China examined the prevalence of COPD among households utilizing biomass cooking fuels. A cluster disproportional random sampling survey (a cluster survey where each cluster is not proportionate to the population size) of 3449 subjects over 40 years of age using biomass, charcoal, or gas fuels was conducted in both urban and rural areas. Pollutants were measured during the cooking process and particles at PM_{10} as well as CO and NO_2 were measured. In addition to the air pollution monitoring, a health survey was conducted between September 2002 and March 2003 asking pertinent health questions, while lung function was tested with a portable spirometer. Upon data analysis, the overall prevalence of COPD in the areas of study was 9.4% with the rural population having a slightly higher prevalence than in the urban setting due to additional risk factors such as smoking. However among non-smoking women in both study areas, the prevalence of COPD was still higher in the rural area than in the urban area (7.2% vs. 2.5%). Of those living in the rural area, 88.1% cooked with biomass fuels and another 10.9% utilized coal in combination with wood or other crop residues. In the urban population, 98.6% of households used LPG stoves. Using univariate and multivariate analysis, the study showed a positive association between exposure to biomass cooking and COPD; biomass fuels are a risk factor for COPD in Southern China (Liu, Zhou et al. 2007).

Kenya

Acute respiratory infections were assessed from 1996-1999 utilizing longitudinal data in rural Kenya to estimate an exposure-response relationship for particles at PM_{10} from biomass combustion. A total of 55 households participated in the study and were monitored for particulate matter. Other elements of the study included assessment of the housing structure and volume, daily activities of all the members of the household (cooking, cleaning etc), and interviews with household members. Data on ill-health focusing specifically on cough and other respiratory ailments were collected by community nurses/ The study provided evidence that exposure to particulates from biomass combustion and the amount of time that a person is exposed increased the risk of ARIs or ALRIs in an increasing function. The intensity of the exposure, as an independent variable, was not found to contribute to the incidence of disease. Exposure above 2,000 $\mu g/m^3$ amplifies the rate of increase in the exposure-response relationship. The results provided evidence that the intensity of smoke and particles for a short period of time does not influence disease by itself, rather only contributes to the total. However, due to the rate of increase for daily exposure above 2,000 $\mu g/m^3$, this study in Kenya proposes that future public health studies should aim to reduce the negative impacts of indoor air pollution and try to decrease exposure to below 2,000 $\mu g/m^3$ (Ezzati and Kammen 2001).

India

The impact of biomass burning on the prevalence of tuberculosis was examined in two studies from India in 1999 and more recently in 2008. The initial study in India utilized data from the 1992-1993 National Family Health Survey to assess self reported cases of tuberculosis with cooking fuel reported by the household. Reported cooking fuels were grouped into two categories for the statistical analysis of the study, biomass including wood and dung, and all cleaner fuels. The study controlled for confounding variables that may have influenced tuberculosis cases including economic status, household material, and average number of people in the room to account for crowding. In addition the analysis accounted for age, gender, and urban/rural location. The study results concluded that the prevalence rate of tuberculosis was higher among households that used biomass fuels (969 per 100,000) when compared to households using cleaner fuels (378 per 100,000) with a p-value of <0.0001. Although the study was unable to assess the true effects of cooking smoke on tuberculosis, it established a link between biomass fuels and TB, by stating that 51% of active tuberculosis cases could be attributable to cooking smoke from biomass fuels (Mishra, Retherford et al. 1999).

The second study investigating the association between biomass fuel burning and tuberculosis was a nested case-control study on 255 cases and 1275 controls in Tiruvallur District, India. In the district, 255 bacteriological-positive cases of tuberculosis were identified and for each case five sex-matched controls were randomly selected from the same village. A questionnaire was administered to the participants requesting health information. Assessment of fuel used in the household was carried out and divided into biomass fuel and non-biomass fuel such as kerosene or other gas fuel. The results of the study showed that households cooking with biomass fuels saw more cases of tuberculosis (Table 5). The study also demonstrated that 36% of tuberculosis cases could be attributed to biomass fuels as opposed to 14% of the cases that could be attributed to smoking (Kolappan and Subramani 2009).

Table 5: Univariate and Multivariate Analysis for Cooking Fuel as a Risk Factor for TB

			Univariate		Multivariate	
	Case	Control	OR (95% CI)	P-Value	OR (95% CI)	P-Value
Non-Biomass Fuel	24	252	1.0		1.0	
Biomass Fuel	231	1023	2.9 (1.8 to 4.7)	<0.0001	1.7 (1.0 to 2.9)	0.04

Intervention Strategies

Much of the research focused on indoor air pollution utilizes evidence for high emission from biomass fuels and assesses intervention strategies to reduce indoor air pollution in a given population. Intervention strategies can be targeted at the source of the pollution, the stove, fuel source, and the living and cooking environment, or the use and behavior of the person who is cooking (Figure 3).

Source	Living Environment	User behaviour
Improved cooking devices • Chimneyless improved biomass stoves • Improved stoves with flues attached	*Improved ventilation* • Hoods / fireplaces and chimneys (built into structure of house) • Windows /ventilation holes	*Reduced exposure through operation of source* • Fuel drying • Use of pot lids • Good maintenance • Sound operation
Alternative fuel-cooker combinations • Briquettes and pellets • Charcoal, Kerosene • Liquid petroleum gas (LPG) • Biogas, Producer gas • Solar cookers (thermal) • Other low smoke fuels • Electricity	*Kitchen design and place-ment of the stove* • Shelters / cooking huts • Stove at waist height	*Reductions by avoiding smoke* • Keeping children out of smoke *Food preparation* • Partially pre-cooked food
Reduced need for the fire • Efficient housing • Solar water heating		

Figure 3: Potential interventions to reduce indoor air pollution (p.21) (Von Schirnding, Bruce et al. 2002)

India

A community project designed to improve air quality in households in Pune, India distributed 30,000 improved cement cook stoves between August 2004 and December 2005. Following the stove distribution 110 households with two types of improved stoves, vented and unvented, were monitored for CO and $PM_{2.5}$ over a 48 hour period. The study revealed that one year following the improved stove intervention CO levels were signficantly reduced among both stove groups when all households were pooled together (Table 6). When only the unvented stoves were assessed for reduction in particulate matter and carbon monoxide compared to traditional stoves, a 49% reduction in $PM_{2.5}$ (p= <0.079) was seen alongside a 30% reduction of CO (p=<0.024). In addition, vented stoves showed a 45% reduction in $PM_{2.5}$ (p=<0.06) and a 45% reduction in CO (p=0.008). Results provided evidence that improved cooking stoves can reduce levels of indoor air pollution in communities that previously used traditional cooking methods. The chimneys on the stoves allowed for harmful particulate matter and CO to be removed from the household and dispersed into the outdoor atmosphere. The successful adaption of these new stoves provided evidence that intervention trials can be successful, but must be introduced into the community in a culturally sensitive manner to see full gains in pollution reduction (Dutta, Shields et al. 2007).

Table 6: Improved cookstoves (vented and unvented) compared to traditional cookstoves

		Before			After				
	N	Mean	SD	Max	Mean	SD	Max	P-value	Mean % change
$PM_{2.5}$ (mg/m^3)	87	1.25	1.61	11.08	0.94	1.05	5.19	<0.007	24
CO (ppm)	98	10.82	8.71	40	6.65	7.1	47.3	<0.001	39

Honduras

In another household study June 2005 in Honduras, 54 households were monitored for CO in addition to 58 households monitored for particulate matter $PM_{2.5}$. The study utilized both households with traditional and improved wood-burning stoves in one semi-urban and one rural community. The household exposure levels were measured with 8 hour indoor monitoring and 8 hour personal monitoring mechanisms. In addition to collecting indoor air pollution measurements, the study focused on collecting information regarding household characteristics to indicate ventilation and examined stove quality in each household. The results of the study showed that women who used improved cooking stoves had 63% lower personal $PM_{2.5}$ levels, 73% lower indoor $PM_{2.5}$ levels, and 90% lower levels of indoor CO when compared to women who used traditional stoves in their homes (Table 7).

Table 7: $PM_{2.5}$ and CO levels for traditional and improved stoves in Honduras

	Total					Improved					Traditional				
	N	Mean	SD	Max	GM	N	Mean	SD	Max	GM	N	Mean	SD	Max	GM
$PM_{2.5}$ 8 hr ($\mu g/m^3$)	57	614.9	847.5	4835.4	329.5	30	255.2	240.2	902.1	178.7	27	1002.3	1089.4	4835.4	650.2
CO 1 hr (ppm)	54	7.9	11.2	54	2	28	1.8	3.2	11.9	0.5	26	14.3	13.1	54	9.5

The study created a four level stove scale ranging from poor functioning traditional stoves to well functioning improved stoves. This stove scale predicted 79% of the variation in pollutant concentrations compared to the simple stove type analysis which only predicted 54% of the variation in concentrations. The Honduran case study shows evidence that both ventilation and stove type and quality can predict emissions and indoor air pollution during cooking (Clark, Reynolds et al. 2010).

Guatemala

Perhaps one the most well known studies examining an intervention to reduce indoor air pollution is called the Randomized Exposure Study of Pollution Indoors and Respiratory Effects (RESPIRE) conducted in Guatemala. In the Mayan community a total of 504 households, using traditional indoor open fires, were randomized to receive a new chimney woodstove (plancha) or remain with their traditional cooking method. The intervention was delivered in two rounds, the first comprised of 300 women occurred between October and November 2002, while the second round included 204 women and occurred between October 2002 and December 2004. The intervention stove was a local Guatemalan stove with a firebrick combustion chamber and metal chimney. Using a questionnaire administered by the research team, the study assessed the health outcomes of the households and measured women at baseline and every 6 months following the intervention up to 18 months. The team also administered spirometric measurements to assess lung function.

Indoor air pollution was measured with personal exposure to carbon monoxide in a 48 hour period. Median CO levels for the intervention plancha group were 1.63 ppm compared to the traditional stove of 4.24 ppm. Lung function was not seen to be affected by the intervention plancha stove, which may have been due to the difficulty in measuring lung function and the learning effect among participants (Table 8). The prevalence of chronic respiratory symptoms also decreased among the women with the intervention stoves (Table 9). The study provided strong evidence, as a randomized trial of reduced carbon monoxide exposure with the improved stove and the intervention group, as well as reduced respiratory symptoms.

Table 8: Lung function changes with plancha intervention stove (Smith-Sivertsen, Diaz et al. 2009) p.216

	Follow-up Time Points Included			
Outcome	6, 12, and 18 months		12 and 18 Months Only	
	β	95% CI	β	95% CI
FEV_1	-0.02	-0.09, 0.04	-0.01	-0.09, 0.05
FVC	-0.04	-0.01, 0.03	-0.04	-0.12, 0.04
(FEV_1 : FVC) X 100	0.41	0.44, 1.27	0.5	-0.42, 1.42

Table 9: Odds ratios for respiratory function with exposure to carbon monoxide (Smith-Sivertsen, Diaz et al. 2009) p.216

Lung Symptom and Quartile of CO Exposure	Odds Ratio	95% CI
Cough		
First	1.0	
Second	2.65	1.29, 5.47
Third	1.68	0.79, 3.57
Fourth	1.72	0.81, 3.65
Phlegm		
First	1.0	
Second	2.99	1.20, 7.46
Third	2.25	0.87, 5.80
Fourth	2.98	1.20, 7.42
Wheeze		
First	1.0	
Second	1.8	0.73, 4.46
Third	2.5	1.03, 6.06
Fourth	2.46	1.02, 5.90
Tightness in Chest		
First	1.0	
Second	2.45	1.02, 5.88
Third	2.6	1.07, 6.30
Fourth	2.35	0.98, 5.65

The plancha intervention stoves reduced the women's exposure to indoor air pollution and the number of respiratory symptoms (Smith-Sivertsen, Diaz et al. 2009).

Perceptions of Indoor Air Pollution among Women

In addition to the health impacts of indoor air pollution, biomass burning participates in the nexus of gender, energy, and poverty. Studies have shown that those living in the most impoverished conditions are forced to utilize biomass fuels, placing a heavy burden on the health of women in households.

In addition to monitoring indoor air pollution in the home the RESPSIRE randomized intervention trial, assessed self-rated health and change in health after 18 months among the women participating in the study. Out of the 504 participants in the RESPIRE trial, 180 women participated in the self-rated study. The answers to the self-rated health questionnaire were assessed with a logistic regression model. When asked if their health had improved in the 18 months since having been involved in the study, 52.8% of the women in the intervention group said their health had improved, while only 24.2% of the women in the control group agreed that their health had improved (p=-0.0001). The women who received the improved plancha stove described their kitchens to have less smoke, and also described the stove to improve their cooking tasks resulting in less worries, and better cooking positions. Among the 89 women who received the intervention stove, 84 saw a reduction of smoke from the new stove and 74 said that the reduced smoke influenced their health (Diaz, Bruce et al. 2008).

Chapter 3: Methodology

Introduction

Population

The population used for this indoor air pollution study consisted of 84 households in Shero-Meda Kebele in Addis Ababa. Households selected for this study were located at the base of Entoto Mountain where many women spend their days collecting firewood from the forest. Quantitative studies were utilized to determine the levels of indoor air pollution. Qualitative methods were used to determine perceptions of cooking.

Research Design

The research design utilized in this study was a mixed methods approach combining both quantitative and qualitative data. The study included three components of equal weights. The quantitative data collection included a household survey, adapted from Berkley Air Monitoring (Appendix 1). In addition, quantitative data monitored levels of carbon monoxide and particulate matter in each household. The third and final component of the study was in-depth interviews and focus group discussions.

Procedures

The households for the quantitative portion of the study were selected on the basis of several criteria. First, the households had to be located in Shero-Meda Kebele. Permission was gained from the Shero-Meda Kebele government office in order to conduct research among the households; the research team was supported by a local kebele official. When selecting households for inclusion in the study the team started systematically at one edge of the kebele and worked among the households with the help of the local guide to find households willing to participate. Households picked for monitoring had a kitchen separate from the main house, enclosed walls and ceiling, and cooked with firewood. As this was an urban setting, the kitchens were traditionally separate from the main living quarters. Due to the urban environment, kitchens were limited in size due to lack of space in the neighborhoods. Due to a limited amount of measuring devices, only six households could be monitored during any 24 hour period.

Air Pollution Monitoring Component

Once a household was selected, the team began their research by explaining the procedure to the household members (most often the wife of the household) and gained verbal consent from the households for participation in the study. Once consent was gained, the research team placed the UCB monitor and HOBO logger in the kitchen. Specific requirements as to where the monitors were placed were observed as best as possible in each kitchen. The requirements were as follows:

1. 100 cm from the edge of the stove (combustion zone)
2. 140 cm above the floor
3. 150 cm from any openable door or window, where possible

Particulate matter was measured in each household by utilizing the University of California Berkeley Particular Monitor (UCB PM) which was set to record the particulate concentration within the household every minute over the 24 hour time period. The UCB monitors were calibrated by the University of California at Berkeley before the start of the project. The project utilized 6 different UCB monitors.

Carbon monoxide was measured during the course of the study with HOBO CO loggers (Tempcon Instrumentation, Arundel, West Sussex, UK) that were calibrated by University of California Berkeley using a CO standard gas of 5 and 60 ppm. The project utilized 6 different HOBO loggers.

The people in charge of cooking were briefed on the equipment and were allowed to ask any questions they had concerning the process. The monitoring equipment was placed in the kitchens and the exact measurements from the stove and windows were recorded by the research team.

Upon completing the 24 hour period, the research team returned to each household and collected the monitors and conducted the post-monitoring questionnaire with the person who cooked during the 24 hour interval. The data were then downloaded to the staff's personal computer as soon as possible after the collection of the devices.

Household Survey Component

At the time of monitor placement the research team also conducted the pre-monitoring data collection which included recordings of the dimensions of the kitchen and types of walls and ceiling (Appendix A). The qualitative portion of the study utilized the Berkley Air Monitoring pre and post monitoring questionnaires to complement the measurements gathered in each household. The pre-monitoring questionnaire was conducted when the team placed the monitors in the kitchens and the post-monitoring questionnaire was completed when the staff came to collect the equipment after 24 hours. The questionnaire had a total of 39 questions and it was designed to provide information about the cooking habits of the household during that specific 24 hour period.

Qualitative Component

The qualitative portion of the study interviewed women from households used in the quantitative research. The women were asked during the time of household monitoring if they would be willing to participate in an in-depth interview or focus group discussion. A total of 5 in-depth interviews and 5 focus group discussions were carried out at the local official's home, the individual's home, or the kebele office. For the qualitative portion of the study the research, staff utilized both in-depth interview guides and focus group discussion guides created before the start of the research.

Data Analysis

Data analysis was conducted with the use of several computer software programs. Data from the University of California at Berkley UCB and HOBO monitors were uploaded in electronic form to the researcher's computer. The UCB Monitor Browser 2.5 was used to assess particulate matter levels while the BoxCarPro 4.3 software was used to work with CO data. Statistical analysis was done in SAS (Cary, NC). Qualitative data was analyzed with MAXQDA software provided by Emory University.

Results

Quantitative Indoor Air Pollution Monitoring

A total of 84 households participated in the household monitoring study and completed the household questionnaire. Upon completion of the household monitoring of particulate matter and CO, 69 households had accurate particulate matter data while 55 had accurate CO data. The weather during the survey period of June-August 2010 was the winter season in Addis and every 24 hour monitoring period included some amount of rain.

The household survey data provided demographic information on the households. (Table 10). Observations at each kitchen provided information on the construction material of each kitchen. Fifteen kitchens were constructed with sheet metal walls, 30 households had mud walls, 2 had concrete walls, 7 had walls made of branches and twigs, and the remaining 27 kitchens had walls constructed of a combination of materials. Some kitchens had one wall as sheet metal, another of plastic sheeting, or patches of materials together (Photo Set 1).

Table 10: Descriptive Household Statistics

Kitchen Variables (Continuous)	Mean	SD
Kitchen Volume (m^3)	15.89319394	7.362195
Kitchen Area (m^2)	6.101569136	2.546859
Hours Stove Lit	2.471830986	2.012261

Kitchen Variables (Categorical)	Frequency	%
Baking Location (N=77)		
Main Kitchen	70	90.91
Secondary Kitchen	1	1.29
Living Room	5	6.49
Door Open (N=80)		
Not at all	2	2.53
Half the Time	55	69.62
All the time	22	27.85
Fuel Used for Baking (N=77)		
Firewood	4	5.19
Branches, Leaves, and Twigs	68	88.31
Dung	2	2.59
Electric	1	1.29
Other	1	1.29
Fuel Used for Coffee And Tea (N=80)		
Charcoal	46	58.23
Kerosene	15	18.99
Firewood	1	1.27
Branches, Leaves, and Twigs	9	11.39
Charcoal and Kerosene	6	7.59
Firewood and BLT	1	1.27
Firewood and Charcoal	1	1.27
Location of Making Tea and Coffee (N=80)		
Main Kitchen	24	30.28
Living Room	54	68.35
Bedroom	1	1.27
Person Cooking (N=80)		
Wife of Head of Household	60	75.95
Daughter of Head of Household	8	10.13

Wife and Daughter of Head of Household	11	13.92
Primary Fuel (N=80)		
Other	1	1.27
Firewood	5	6.33
Branches, Leaves and Twigs	73	92.41
Primary Stove (N=80)		
Three stones fireplace	61	77.22
Clay improved 3 stones fireplace	10	12.66
Improved Wood Burning	2	2.53
Metal Charcoal Stove	1	1.27
Metal Ring Stand	3	3.8
Other	2	2.53

Photo Set 1: Kitchens Monitored for Indoor Air Pollution. Kitchens were a separate unit from the household and constructed from sheet metal, mud, and other materials

The survey demonstrated that 90% of the households baked in the separate and main kitchen; kitchens ranged in volume from 3.54 m^3 to 42.29m^3. The wife of the head of the household was the main cook in 75.95% of the households. The primary fuel used among the households was branches, leaves and twigs (92.41%). Most households stated that they used branches, leaves and twigs for fuel during baking (88.31%); the making of coffee and tea was done in the living room (68.3%) with charcoal (58.23%) (Photo set 2).

Photo Set 2: Examples of fuel wood used by the women in Shero-Meda. On the left is the fuel termed branches, leaves and twigs, and on the right is chopped firewood.

Most households cooked on the 3 stone traditional fire places while other stoves were found in a few kitchens (Photo set 3, picture 1). Three kitchens had a metal ring stand, and another had an improved wood burning stove (Photo set 3, picture 2).

Photo Set 3: Examples of traditional stoves

Picture 1

Picture 2

Picture 3

Exceedances of EPA Air Quality Standards were seen with the indicators of air pollution during the testing, particulate matter and CO. The EPA states that CO should not reach above 9ppm for an 8 hour average. Of the households sampled, only 29 of the 54 households upheld EPA standards while the other 26 were above 9ppm. EPA standards state for $PM_{2.5}$ that levels should not reach above 35 μg/m^3 in a 24 hour time period (Table 11). Every household sampled exceeded this standard by significant amounts with the lowest $PM_{2.5}$ 24 hour average being 136.137 μg/m^3. Both outcome variables $PM_{2.5}$ and CO were abnormally distributed with a right skew.

Table 11: Outcome Variables $PM_{2.5}$ (μg/m^3) and CO (ppm) levels

	N	Mean	Standard Deviation	Range
$PM_{2.5}$ Geometric Mean	69	793.38	1580.21	136.14 – 12,737.19
CO Average (8 hr)	54	16.08	18.81	0.66 - 69.65
CO Max	54	112.00	179.83	4.2 -1176

Statistical correlations were examined using linear regression modeling, between variables and the outcomes of interest; CO and $PM_{2.5}$. Both CO and $PM_{2.5}$ were log transformed in order to normalize the data. The major variables examined in the model were variables that may have some influence on ventilation in the kitchen. The main variable of interest was size of the kitchen, divided into two categories: less than 15m^3 and kitchens greater or equal to 15m^3. Also included were statistics as to the presence of a window and whether it was open during cooking the number of hours spent cooking and the maximum temperature in the kitchen during the time of cooking. Upon statistical analysis with CO as the dependent variable, kitchens that were less than 15m^3 were seen to have significantly higher 8 hour carbon monoxide averages ($t=9.05$, $p=<0.001$). In addition two variables, maximum temperature and kitchen size, were found to significantly explain the difference in the CO 8 hour average during cooking while controlling for the other variables of interest. There was a statistically significant linear association between the 8 hour CO maximum and maximum temperature during cooking as well as kitchen size (R^2=0.36). For each unit increase in maximum temperature there was a 0.1042 unit increase in the 8 hour CO average (SE=0.024). In addition in the model, for every unit increase in kitchen size there was a -0.89 unit decrease in 8 hour average CO levels (SE=0.32).

Upon examining the dependent variable $PM_{2.5}$ in a linear regression model, there were no variables that were found to be significantly related to the amount of particulate matter in the kitchens during cooking.

Qualitative Findings

Women chosen from the quantitative portion of the study to participate in in-depth interviews discussed issues on cooking and fuel use in their homes. The women discussed fuel price, where fuel is bought, and opinions about each fuel including firewood, kerosene, and charcoal.

Fuel Choice and Use

The women of Shero-Meda generally buy their firewood including chopped wood and branches, leaves and twigs from other women who bring the wood down from Entoto Mountain situated directly behind the town. Firewood is brought by the fuel wood carriers and then sold to or at nearby markets. Women in Shero-Meda state that it is often easier to buy directly from the carriers as they come down the mountain (Photo set 5, pictures 1 and 2). Firewood is described as ranging in price from about 50 to 60 Birr per load, depending on the amount of fuel. The amount of time that one load will last the women varied with the amount of time they cook. One woman stated that one load would last her about three days, and another said that she buys about 3 loads per week. Another woman estimated that about 60 Birr ($3.57) worth of fuel could make approximately 120 injera. All women shared the same sentiment that firewood cooks extremely fast, much faster than charcoal. Firewood however was often discussed in a negative light and tied closely to economic necessity.

"I don't have any other choice; this is the only choice that I have. I can't afford to use other things like gas and electricity. I use what I can get." -Int. 5

In general, women use firewood for cooking their main meals inside the main kitchen. Women cook injera, wot, shiro, and other sauces with the firewood. Many women also describe using the firewood for baking purposes, such as bread, and for roasting barley which after fermenting makes a local alcoholic drink.

Women also discussed the role of kerosene in the household. Unlike the purchase of firewood which is done in the neighborhood and in the local markets, women described kerosene as needing to be bought from larger markets. Markets such as the Sadist Kilo and Arat Kilo markets were utilized for purchasing fuel in amounts larger than 1 liter, especially in 5 liter increments. The Sadist Kilo and Arat kilo markets are a fair distance (approximately 2 km) from the Shero-Meda area and women must take a 1 Birr taxi to reach these markets. Kerosene in 1 liter bottles was described as being purchased in smaller kiosks in the Shero-Meda area or from the gas stations. Kerosene costs 9 Birr for 1 liter. Kerosene was generally described as being used for smaller morning meals or snacks. Kerosene was described as being fast but too expensive to be used for general meal cooking.

"If I have to go somewhere or meet with some people, I would rather use kerosene because it is faster." –Int. 6

Women say that given the economic ability they would prefer to use kerosene over firewood or charcoal due to its fast burning and reduced release of smoke.

Charcoal like firewood was described as being bought in the neighborhood in small amounts. Women spent about 2-3 Birr on the charcoal and utilized it for reheating food or making tea and coffee. Charcoal is also commonly used inside the home versus in the kitchen and provides warmth to the homes in the winter time.

"For instance I use charcoal because it gives heat in our house" –Int.2

Charcoal can be bought in large sacks for about 120 Birr per sack; however the women said this was too expensive and reported buying charcoal on a daily basis.

"Yes all my life, it is going to be 16 years since I got married and had kids and I have been using charcoal all that time. In the good old days I used to buy a quintal of charcoal for 60 birr and that used to last me a month; these days that is impossible, I buy charcoal daily." –Int. 1

Fuel consistency was discussed as women described that fuel choice often changed depending on their disposable income and the price of fuel at the time. Prices of each fuel have been on the rise and women question the future and the expenses they will continue to have to pay in order to cook. The women have noticed that there is extensive deforestation on Entoto and this is a major cause of concern.

"*The fuel choice changing, because if the eucalyptus tree may disappear we will lose everything, therefore the cooking fuel is not consistent. But, I don't know what will happen in the future." –Int. 3*

Health Impacts

Women in the households described many health issues related to their cooking process. General sentiments included that the cooking process, especially with firewood, caused the women's eyes to burn and tear up. Women described kerosene fuel as being a more clean fuel but the smell often causes headaches. Firewood smoke was described to cause the eye problems, coughing, and heart problems. Several women specifically named asthma as a result of cooking with biomass fuels.

"It [firewood] makes you sick, it blinds your eyes, it causes asthma and it makes me cough. Even if we went to the doctors with a problem caused by the smoke they would have no solutions. The smoke gets in the eyes until the only thing left is tears. It also gets in the stomach, which is very painful." –Int. 4

One woman even stated that she had pneumonia in the past 6 months which could be irritated by cooking meals with biomass fuels.

Income Generating

Women were asked about their role in the household and to describe their daily activities. Women generally described that their role in the household was to cook and take care of the children; in some instances they were they not only caregiver for the family but also the head of household. Women who did partake in income generating activities sold small items in the market such as vegetables and lentils.

In addition to cooking for the family, several women reported small household income generating cooking projects. One woman, when asked about her cooking routine, described cooking injera that would be sold to customers in the neighborhood. She stated that she can sell between 40-100 injera in a day (Photo set 4, picture 1).

"Today I made 40 injera. If the injera ends quickly I will start making some more. The amount of injera I sell per day depends on the market. There are days when I sell 100 injera on order but I almost always sell 40 injera." –Int. 1

Another woman utilizes her time in the kitchen to make korefe, a local drink made from fermented barely. The process is lengthy but includes cooking large amounts of barely in order to ferment and prepare the drink. In addition to these two income activities, women were noted to make bread to sell to neighbors (Photo set 4, pictures 2 and 3).

Photo Set 4: Women utilize their cooking time to make bread or injera to sell in the neighborhood

Picture 1

Picture 2

Picture 3

Discussion of Fuel Wood Carriers in the Entoto Area

As Shero-Meda sub-city sits at the base of Entoto Mountain, many women in the community are involved, or previously were involved, in collecting the firewood that is used for cooking from the mountainside. Women in the in-depth interviews were asked about the fuel wood carriers in order to understand their role in the community. One woman used to be a fuel wood carrier, as well as a part of the firewood carriers union. She stated that as a fuel wood carrier herself, she and several other women would go in groups to collect firewood as often as needed, but mostly 2-3 times per week. Collecting the fuel wood would take all day and was described as being very strenuous because it involves climbing the mountain and carrying large amounts of wood on ones back. During the winter season the weather is often rainy and very cold and the fire wood collectors endure harsh weather conditions. Women also discussed entrance into the forest where guards would harass the young women, occasionally ending in beatings or even rape. One woman discussed her experience as a former fuel wood carrier. She described the work as difficult and dangerous.

"It is very far it would take the whole day to go and collect firewood. If we left 6 in the morning we would return 6 at night. We even take our lunches and water. The path is very difficult there are many ups and downs".

"Yes, the guards would hit us, tell us to return it or make us pay so that we could pass. There is the problem of falling and breaking our bones; it is very difficult and tiresome. There is also the possibility of being raped. There are lots of problems."

Photo Set 5: Women buy firewood from others carrying it down from Entoto or from the local neighborhood market

Picture 1

Picture 2

Children Under Five

One woman described that she carried her 2 year old child into the kitchen with her while she cooked.

"I take care of her while working, sometimes I make 50 injeras whilst holding her. I have to take care of her she is my blood. I carry her on my back while I work. For two years I have been taking care of her and working at the same time." –Int 1

Discussion

Quantitative

The results from the modeling exercise to determine ventilation factors that affected the 8 hour CO average levels provided evidence that the size of the kitchen as well as the maximum temperature observed during the cooking period were significantly related. It should be noted however, that only 54 households were included in the analysis as several households did not properly collect CO data. Maximum temperature in the kitchen increased during cooking (mean=26.14°C, range= 19.74, 36.03°C) and levels of CO correlated significantly with this increase in temperature. The size of the kitchen played a significant role in the CO 8 hour average. Kitchens less than $15m^3$ had significantly higher levels of CO during the cooking period, than the larger kitchens.

This is a crucial point in determining factors in the kitchen construction that could reduce levels of air pollution. The area is very hilly as it backs up to Entoto Mountain, and therefore flat space is difficult to find in order to construct a large kitchen. Many kitchens were observed to be almost impossible for the cooks to stand fully upright in (Photo Set 6, picture 2 and 3). Women with smaller kitchens were therefore seen to experience higher levels of CO in the household which may lead to negative health outcomes in the future. This result demonstrates the intensity of CO levels in kitchens that are very small. Many of these women may also be among the most impoverished as their kitchen size may be a reflection upon the amount of land or money that was available to construct a larger kitchen.

Photo Set 6: Examples of kitchens that were monitored for indoor air pollution

Picture 1

Picture 2

Picture 3

Qualitative

Previous research on indoor air pollution exposure has been based predominately in rural locations. The current study provides an example of the necessity to investigate urban indoor air pollution especially in the Sub-Saharan African context.

The qualitative findings in this study are a unique addition to the measured particulate matter and carbon monoxide levels. Women's voices often go undocumented when conducting only quantitative research and the rest of their story is discarded. The qualitative findings in this study provide a background story for the high levels of indoor air pollution seen in the Shero-Meda households cooking with firewood. The in-depth interviews and focus group discussions also shed light to the difficulties of cooking with firewood, daily activities of women, and hopes and dreams about their futures.

Initially, women interviewed provided insight into reasons behind fuel choice. It has been noted in the literature that a energy-poverty-gender nexus exists (Cecelski 2000). The nexus reflects the theory that biomass burning impacts primarily women with low economic incomes. The interface of energy, poverty, and gender however has most often been examined in rural communities. There has been little consideration that women living in urban areas in Sub-Saharan Africa may face the same struggle of having no other fuel choice other than biomass due to their economic capacities.

The women in Shero-Meda expressed their fuel choice in terms of "not having a choice" other than to use firewood. Women would rather cook with more clean burning fuels like kerosene; however, they do not have the economic control to do so. Women expressed that kerosene cooked food faster than firewood, but prices were extremely high. Charcoal, unlike firewood and kerosene, was used primarily by the women in Shero-Meda for heating the household and making tea and coffee which is done many times during the day.

Another interesting point that came about in the discussions of fuel wood was the how and where the women purchased their fuel. Women in Shero-Meda purchase their fuel wood in several day intervals and did not buy the fuel in large quantities, which is most likely due to their lack of purchasing power. Both the firewood and charcoal that women use are bought in the local neighborhood at their convenience several times a week; however, women must travel by taxi in order to purchase kerosene. The additional money needed to purchase kerosene only compounds its already expensive cost.

Women who are cooking with firewood in Shero-Meda sub city are not doing so because they believe that firewood is the best or cleanest fuel. The women are cooking with firewood out of a last resort due to their low income and economic status. The option of which fuel to use rarely crosses the women's mind unless they are describing the fuel they would one day hope to use.

The discussion of the cooking process among the women documented the amount of time women spent cooking and the ways in which they provide for their families. As women often spent a majority of their day cooking (range 1.0-12.5 hours, mean 4.75 hours), it was revealed that income generating projects have sprung from the cooking business. Women participated in selling injera, bread and local drinks to their friends and neighbors, to supplement income. As with biomass fuels, there is no easy regulation of the cooking time or on-off button. The fuel will continue to burn and therefore waste money if not used until its last potential. Women were very practical about their time and money while cooking.

Knowledge of biomass fuels and its impacts of the health of women were explored among the community. Women described symptoms of discomfort and pain while cooking. They noted that the eye problems and coughing were major concerns of cooking with firewood. Their link between their symptoms and cooking with firewood was evident and allows us to know that women do have some understandings of cooking with firewood on their health. Women, however, seemed not to have in-depth knowledge about other health impacts besides minor and acute problems. In addition to their own symptoms, women seemed not to note the importance of keeping small children out of the kitchen. One woman reported that she took her baby into the smoky kitchen every time she cooked. This lack of knowledge about the extremely dangerous health outcomes of smoke on young children needs to be addressed among the community.

It was seen from the quantitative portion of the study that levels of CO and $PM_{2.5}$ greatly exceeded indoor standards and have great potential to cause lasting health effects on both the women and small children.

One of the most pertinent issues among the women living at the base of the Entoto Mountain is the issue of collecting fuel wood from the forest. If they are not continuing the job currently, most women in Entoto reported previous experience as a fuel wood carrier. The in-depth interviews aimed to provide insight onto the knowledge of women about the fuel wood carriers and real life experiences as having been a fuel wood carrier previously. Women described the harsh conditions that fuel wood carriers endure and provided evidence of events of rape and beatings while collecting fuel. The journey of collecting fuel is often seen as one of the most pressing issues among communities who cook with biomass fuels. It is important that the

Shero-Meda community and Addis Ababa government address issues of fuel gathering and provide alternatives for women in low income areas to make an income.

Ultimately the women in Shero-Meda described their concerns about the future, deforestation occurring on Entoto Mountain and ever rising fuel cost. Firewood is becoming scarcer as deforestation occurs and the price of kerosene continues to rise. The price of kerosene in Addis Ababa has more than tripled since 2007 when a liter of kerosene cost 4.15 Birr ($0.25). In March 2011, a liter of kerosene cost about 14.05 Birr per liter. This drastic increase in fuel price provides no other option for those women in low income neighborhoods than to continue to utilize firewood as their primarily fuel. In the cycle of fuel use, the increased usage of firewood leads only to more deforestation of the mountain and increased firewood costs. Ultimately firewood prices will rise drastically until there is no more local firewood in the area.

Limitations

Conducting the study in an urban environment proved to add many obstacles to the monitoring process. A limitation of the quantitative indoor air pollution study is the difficulty of working in an urban setting where households have been constructed with whatever materials are available. When placing the monitors in the households, it was often difficult to find an available space where the monitors could be hung the correct distance from the fire as recommended by Berkley Air Monitoring. In addition, the kitchens often had two separate spots for cooking, one place where the women cooked shiro and other wots or stews, and a different location for making injera. The staff team used their best judgment to determine the most appropriate spot for the monitors. In the smallest of kitchens, it was found that many times the most appropriate distance to place the monitor from the stove and door did not exist, because the kitchen was smaller than the required distance to place the monitors. In these instances the monitors were placed as far away from the door and stove as possible.

Levels of particulate matter and carbon monoxide may have also been influenced by the construction of the kitchen. When assessing the construction of each kitchen, the kitchens were constructed with materials available to the women in Shero-Meda; these included combinations of mud, sheet metal, and branches. Due to the variability in construction of the kitchens, various wall types determined in part the amount of ventilation in each kitchen. Kitchens were chosen because they were fully enclosed; however there were several kitchens that had large gaps between the walls and roof (Photo set 6, picture 1). Other kitchens had walls constructed of branches and twigs and had large gaps in the wall allowing additional ventilation and smoke to escape the kitchen area. In addition, due to the gaps between walls, or walls and the roof, it is possible that mixing of outdoor air pollution may have had a slight impact on indoor air quality. In order to account for any large sources of outdoor pollution, researchers made note of any outdoor fires or other sources of pollution close to the home; however, this may not account for all outdoor and indoor air mixing.

In addition, several of the CO and UCB monitors were not always functioning correctly.. The monitors used for the collection had been used in several previous studies including harsh conditions in the desert in Eastern Ethiopia; 54 out of 83 CO monitors collected data (65%) while 69 out of 83 UCB monitors collected data (83%).

One final limitation of the monitoring study is the comparison of the indoor air pollution rates to the EPA ambient air quality standards. This technique is used to assess the high levels of indoor air pollution but it must be noted that the EPA standards are aimed to assess outdoor ambient air, not indoor air. There are currently no indoor air quality standards, and most scientists employ the comparison of indoor levels to the EPA ambient standards as a reference.

Recommendations

Given that the CO 8 hour average levels, CO maximum levels, and $PM_{2.5}$ 24 hour averages were all well above EPA standards, additional research should be conducted to examine urban indoor air pollution in Sub-Saharan Africa (Table 12). First, special attention should be paid to kitchen construction, especially if the kitchen is a separate unit from the house itself. The materials that the kitchen is made out of, although not significant in the model, did show some correlation to the amount of indoor air pollution.

Table 12: EPA Standards for $PM_{2.5}$ and CO with Levels Seen in Shero-Meda

Pollutant	**EPA Guidelines**		**Range of Ambient Levels in Shero-Meda Study**
	Period	*Level*	
Particulate Matter $PM_{2.5}$	24-hour	35 µg/m3	136.14 – 12,737.19 µg/m3
Carbon Monoxide (CO in ppm)	8-hour	9 ppm	0.66 - 69.65 pmm

In addition to improving the kitchen and cooking environment it is vital that new stove technologies that are economically viable be introduced in Addis Ababa. The switch from burning biomass fuels by low income households in Addis should be addressed by the Ethiopian government with local and international NGOs. New stove and fuel technologies such as the ethanol burning CleanCook stove produced by Dometic INC and distributed by Gaia Association provides a cleaner and safer stove that can cook more efficiently than firewood at a fraction of the cost of kerosene. The ethanol used for the stoves can be produced locally in micro distilleries from the waste product of sugary fruits and vegetables that are plentiful in the country. These types of stoves interventions should be promoted in the city with efforts from the community in collaboration with Gaia Association. Not only would these interventions reduce the health burden of cooking with biomass fuels among the women, it would reduce deforestation in Ethiopia and provide small businesses in the communities that makes the ethanol. With the adaption of improved stoves, Addis Ababa can launch a campaign to reduce the burden of disease in the country and set an example for other countries in the region.

Gaia CleanCook stove with traditional Ethiopian coffee pot (Courtesy Project Gaia, http://www.projectgaia.com/page.php?page=gallerycleancook#img/gallery/cleancook/02.jpg)

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Appendix A

Indoor Air Pollution: Post-Monitoring Questionnaire (University of Berkeley)

INSTRUCTIONS: Answer each question by circling and/or writing the appropriate number. **Questions 1-7** are general household (HH) observations and can be completed **before** the IAP monitoring is finished. **Questions 8-38** must be completed **after** the monitoring period is completed.

Beginning of Pre-Monitoring Questions

1. (Observe) Where do they cook?.....................

main kitchen	1
secondary kitchen	2
living room	3
bedroom	4
outside	5
other (specify):	6

2. (Observe) How many walls does the main kitchen have?....................

no walls	0
one wall	1
two walls	2
three walls	3
four walls	4

3. (Observe) What type of walls does the main kitchen have?

solid wood	1
sheet metal	2
fence (porous, sticks, bamboo)	3
mud	4
concrete	5
Plastics	6
other:	7

4. (Observe) What type of roof does the main kitchen have?

no roof	0
thatch	1
sheet metal	2
ceramic tiles	3
solid ceiling	4
plastic	5
other	6

5. (Measure) What is the length (longer dimension) of the main kitchen? _____ **meters**

(0 if not applicable)

6. (Measure) What is the width (shorter dimension) of the main kitchen? _____ **meters**

(0 if not applicable)

7. (Measure) What is the height of the main kitchen?.................................._____ **meters**

(0 if not applicable)

8. (Observe) Are there open eaves between the walls and roof of the main kitchen area?

no	1
yes, less than 30 cm	2
yes, more than 30 cm	3

End of Pre-Monitoring Questions

Beginning of Post- Monitoring Questions

9a. (Ask/Observe) What was the **primary stove** used during the monitoring period for **cooking in the main kitchen**?

three stones	1
clay (three-stones)	2
Improved wood burning	3
metal charcoal stove	4
lakech charcoal stove	5
kerosene stove (China)	6
pressurized kerosene stove	7
metal ring stand	8
CleanCook alcohol stove	9
Other	10

9b. (Ask) What was the **primary fuel** used during the monitoring period in your home for **cooking in the main kitchen**?

(Circle only one fuel)

kerosene	1
firewood	2
charcoal	3
branches, leaves, & twigs (BLT)	4
tiftif (charcoal and dung balls)	5
ethanol	6
dung	7
other	8

10a. (Ask/Observe) What was the **secondary stove** used during the monitoring period for **cooking in the main kitchen**?

no secondary stove	0
three stones	1
clay (three-stones)	2
metal ring stand	3
metal charcoal stove	4
lakech charcoal stove	5
kerosene stove (China)	6
pressurized kerosene stove	7
Other (specify):	8

10b. (Ask) What was the **secondary fuel** used during the monitoring period for **cooking in the main kitchen**?

(Circle only one fuel)

kerosene	1
firewood	2
charcoal	3
branches, leaves, & twigs (BLT)	4
tiftif (charcoal and dung balls)	5
electricity	6
dung	7
other (specify):	8

11a. (Ask/Observe) What **stove** was used during the monitoring period for making **coffee and/or tea**?

no coffee or tea was made	0
three stones	1
clay (three-stones)	2
metal ring stand	3
metal charcoal stove	5
lakech charcoal stove	6
kerosene stove (China)	7
pressurized kerosene stove	8
CleanCook alcohol stove	9
other	10

11b. (Ask) What **fuel** was used during the monitoring period for making **coffee and/or tea**?

(Circle only one fuel)

no coffee or tea was made	0
charcoal	1
kerosene	2
firewood	3
branches, leaves, & twigs (BLT)	4
tiftif (charcoal and dung balls)	5
Ethanol	6
Other	7

11c. Where was the **coffee/tea** stove used?

main kitchen	1
secondary kitchen	2
living room	3
bedroom	4
outside	5
other (specify):	6

12a. (Ask/Observe) What **stove** was used during the monitoring period for **baking in the main kitchen**?

no baking in main kitchen	0
three stones	1
clay (three-stones)	2
CleanCook alcohol stove	3
Improved wood burning	4
other	5

12b. (Ask) What **fuel** was used during the monitoring period for **baking in the main kitchen**?

(Circle only one fuel)

no baking in main kitchen	0
firewood	1
sawdust	2
branches, leaves, & twigs (BLT)	3
dung	4
straw	5
coffee husks	6
CleanCook alcohol stove	7
other	8

12c. Where was this **baking** stove used?

no baking at all	0
main kitchen	1
secondary kitchen	2
living room	3
outside	4
other (specify):	5

13. (Ask) How much fuel did you use during the monitoring period for **cooking** with the **primary** stove in the main kitchen? **Cooking of food and Baking**

specify amount & unit:	

example:
camel load, woman load, child load , Kg

14. (Ask) How much fuel did you use during the monitoring period for **cooking** with the **secondary** stove in the main kitchen?

specify amount & unit	

example: camel load, woman load, child load , K

<u>Cooking pattern questions.</u>

16 and 17. Who cooked in the main kitchen during the monitoring period?

Role	**Name:**	**1st cook (#17)**	**2nd cook (#18)**
maid		1	1
wife of HH head		2	2
daughter of HH head		3	3
other:		4	4
no 2nd cook			0

people	

18. During the 24/48hr MP, how many people were **cooked** for in the **main kitchen** (on average)?

19. During the 24/48hr MP, how **many hrs** was the **primary** stove lit for **cooking in the main kitchen**? **(Cooking/Baking)**

hours	

20. During the 24/48 MP, how **many hrs** was the **secondary** stove lit for **cooking in the main kitchen**? **(Coffee/Tea)**

hours	

21. During the monitoring period, was there anything unusual about your stove use pattern?

no, nothing unusual	0
yes, cooked/baked for more people than usual	1
yes, cooked/baked for fewer people than usual	2
yes, other (specify):	3

<u>Questions about other combustion in and nearby the house</u>

22. Did you light any non-electric lamps in or nearby the main kitchen?............

example: candles

no	1
yes	2

not applicable (no lamps used)	0
kerosene	1
candle wax	2

23. What kind of lamp did you use in the main kitchen?

other (specify):	3

Questions related to household ventilation

33. (Observe) How many windows or openings are in the main kitchen?

number	

34. (Ask) Were the windows in the main kitchen open during the monitoring period?

not applicable (no windows)	0
no, not open at all	1
yes, about half of the time	2
yes, open almost all of the time	3

35. (Observe) How many doors are in the main kitchen?.......................

number	

36. (Ask) Were the doors in the main kitchen open during the monitoring period?

not applicable (no doors)	0
no, not open at all	1
yes, about half of the time	2
yes, open almost all of the time	3

very good	1

37. (Observe) How is the ventilation in the main kitchen?................

good	2
fair	3
poor	4

Questions about special conditions

38. (Ask or Observe) Did any of the following weather conditions occur during the monitoring period?

no rain	0
drizzle (light rain)	1
rain	2
Wind/dust	3
Other:	4

39. (Ask or Observe) Were there any disturbances to the monitoring equipment?

Ex: children touched it

no	1
yes	2
describe:	

Supervisor Check:

Name ______________________________

Date (dd/mm/yy) ________________

Comments____

____

____

Appendix B

EMORY UNIVERSITY | Institutional Review Board

TO: Megan Graham
Principal Investigator

CC: Sarnat Stefanie Envir & occup Health

DATE: May 10, 2010

RE: **Notification of Exempt Determination**
IRB00042077
A Mixed-Methods Approach to Assessing Indoor Air Pollution and Perceptions of Cooking among Women in Kebrebeyah Refugee Camp, Ethiopia

Thank you for submitting an application in eIRB. We reviewed the application and determined on **05/10/2010** that it meets the criteria for exemption under 45 CFR 46.101(b)(2) and thus is exempt from further IRB review.

This determination is good indefinitely unless something changes substantively in the project that affects our analysis. The PI is responsible for contacting the IRB for clarification about any substantive changes in the project. Therefore, please do notify us if you plan to:

• Add a cohort of children to a survey or interview project, or to a study involving the observation of public behavior in which the investigators are participating.
• Change the study design so that the project no longer meets the exempt categories (e.g., adding a medical intervention or accessing identifiable and potentially damaging data)
• Make any other kind of change that does not appear in the list below.

Please do not notify us of the following kinds of changes:

• Change in personnel, except for the PI
• Change in location
• Change in number of subjects to be enrolled or age range for adults
• Changes in wording or formatting of data collection instruments that have no

substantive impact on the study design

For more information about the exemption categories, please see our Policies & Procedures at www.irb.emory.edu. In future correspondence about this study, please refer to the IRB file number, the name of the Principal Investigator, and the study title. Thank you.

Sincerely,

Carol Corkran, MPH, CIP
Senior Research Protocol Analyst
This letter has been digitally signed

Appendix C: Consent Forms

Emory University Rollins School of Public Health

Consent to be a Research Participant (Indoor Monitoring)

Title: A Mixed-Methods Approach to Assessing Indoor Air Pollution and Perceptions of Cooking among

Women in Kebrebeyah Refugee Camp, Ethiopia

Principle Investigator: Megan Graham

Funding Source: N/A

Introduction: Good afternoon. My name is Megan Graham. Thank you for allowing me to visit your home.

The Research Study:

We are asking you to participate in this research study to learn about indoor air pollution when using different types of fuels while cooking, including firewood, charcoal, kerosene and ethanol. Participation is entirely voluntary and you may withdraw from the research at any point you choose.

I am researching pollution from cooking among your community. I hope to gain information to benefit your community with more efficient, less expensive, and healthier fuel choices for cooking.

You have been chosen to participate in this study and will assist in providing us information along with 75 other women age 18-49.

Process:

In order to collect data on the pollution produced inside your home during cooking, we will work with you for 2 days while you cook your daily meals. We will use two different pieces of equipment that will collect particles from the smoke that comes from your cooking. (Show the participant the devices). I will place these monitors here on the wall. I ask that you not remove the devices during the 2 days or touch them. They should make no noise and only this small blue light will blink.

Once I place these on the wall, you may in fact forget they are here. You may cook as normal.

I will return to check on the monitoring device after the first day and feel free to ask one of the Gaia staff members if you have any problems.

Risks:

Your participation in this study is limited to the 2 day cooking period and you should endure no risks.

Benefits:

You may not benefit from this study personally, however we hope information learnt from this study may benefit your community in the future.

Payment:

For allowing us to collect data on the smoke from your cooking we will compensate you with the food you cook over these 2 days.

Confidentiality:

There may be several people associated with the study team including myself, research assistants, or other professors at Emory University that may have access to the data gathered. The research team for this project must abide by the ethics regulations and will not share any information from this study with others. All Emory University faculty and staff are also held by law to not discuss any information learnt. All things information learned in this study are to remain confidential.

Do you understand your participation in this study? Do you have any questions or concerns about the monitoring devices or about the cooking process?

Questions:

If you have any questions regarding this study please contact Megan Graham at (local number) or at mgraha4@emory.edu. If you have questions about human subject rights please contact the Emory Institutional Review Board at 001+404-712-0720 or Emory University, IRB 1599 Clifton Road, 5th Floor, Atlanta, GA, 30322, USA.

Verbal Consent:

I am giving you an information sheet that you may keep for personal information. Please do not consent to participation in this study if you have not had a chance to ask questions or are unsure about your participation in any way.

Please ask me if you have any questions regarding the study.

If you are ready to give your consent we will do that at this time. Do I have your consent (permission) to use the information you provide me today in my research? Thank you for your consent.

Continue on with placement of monitoring devices:

Now that we have discussed the purpose of this study and your participation in the study, shall we initiate the research?

Emory University Rollins School of Public Health

Consent to be a Research Participant (Interview)

Title: A Mixed-Methods Approach to Assessing Indoor Air Pollution and Perceptions of Cooking among

Women in Kebrebeyah Refugee Camp, Ethiopia

Principle Investigator: Megan Graham

Funding Source: N/A

Introduction: Good afternoon. My name is Megan Graham. Please help yourself to some refreshments, and thank you so much for your attendance.

The Research Study:

We are asking you to participate in this research study to learn about your perceptions and experiences with different types of fuels while cooking, including firewood, charcoal, kerosene and ethanol. Participation in this interview is entirely voluntary and you may withdraw from the study at any point you choose. There are no benefits that will come from participation.

I am researching cooking and fuel choices among your community. I hope to gain information to benefit your community with more efficient, less expensive, and healthier fuel choices for cooking.

You have been chosen to participate in this study and will assist in providing us information along with 80 other women age 18-49.

Process:

The interview will proceed and we will discuss a number of issues surrounding fuel choice and your experiences with cooking. The discussion will be facilitated by me (Megan Graham) or another one of the 3 research assistants working with me.

Risks:

Your participation in this study is limited to a 1 time conversation and you should endure no risks.

Benefits:

You may not benefit from this interview personally; however we hope information learnt from you may benefit your community in the future.

Payment:

No monetary payment will be provided to research participants.

Confidentiality:

There may be several people associated with the study team including myself, research assistants, or other professors at Emory University that may have access to this interview. The research team for this project must abide by the ethics regulations and will not share any information with others. All Emory University faculty and staff are also held by law to not discuss any information learnt. All things discussed in this interview are to remain confidential. I will not use your name or any other personal information from this interview in my research.

Do you understand that no personal information will be used from this interview?

Does anyone have any questions about confidentiality?

Recorder:

It will be important after the interview is over that I am able to recall what is said in this interview. In order to remember what was said I would like record this conversation. (Show individual the recorder). The information recorded will be brought back to the United States and Emory University in a digital file.

The digital recorder will be locked with the researchers at all time, and no one will have access to the recorder except for the research team members. The Emory Institutional Review Board, a federally regulated institution that handles research with human subjects, does however have a right to review the records if necessary.

Is it ok that I use this digital recorder during our conversation?

Thank you for allowing me to use the recorder, and as we discussed before, everything will remain confidential.

Questions:

If you have any questions regarding this study please contact Megan Graham at (local number) or at mgraha4@emory.edu. If you have questions about human subject rights please contact the Emory Institutional Review Board at 001+404-712-0720 or Emory University, IRB, 1599 Clifton Road, 5th floor, Atlanta, GA 30322, USA.

Verbal Consent:

I am providing you an information sheet that you may keep for personal information. Please do not consent to participation in this study if you have not had a chance to ask questions or are unsure about your participation in any way.

Please ask me if you have any questions regarding the study.

If you are ready to give your consent we will do that at this time. Do I have your consent (permission) to use the information you provide me today in my research? Thank you for your consent.

Continue on to Discussion:

Now that we have discussed the purpose of this study and your participation in the study, shall we move onto the interview?

Emory University Rollins School of Public Health

Consent to be a Research Participant (Focus Group)

Title: A Mixed-Methods Approach to Assessing Indoor Air Pollution and Perceptions of Cooking among

Women in Kebrebeyah Refugee Camp, Ethiopia

Principle Investigator: Megan Graham

Funding Source: N/A

Introduction: Good afternoon. My name is Megan Graham. Please help yourself to some refreshments, and thank you so much for your attendance.

The Research Study:

We are asking you to participate in this research study to learn about your perceptions and experiences with different types of fuels while cooking, including firewood, charcoal, kerosene and ethanol. Participation in this group discussion is entirely voluntary and you may withdraw from the discussion at any point if you choose. There are no benefits that will come from participation.

I am researching cooking and fuel choices among your community. I hope to gain information to benefit your community with more efficient, less expensive, and healthier fuel choices for cooking.

You have been chosen to participate in this study and will assist in providing us information along with 80 other women age 18-49.

Process:

The focus group discussion will proceed with a group of 8-10 women and we will discuss a number of issues surrounding fuel choice and your experiences with cooking. The group discussions will be facilitated by me (Megan Graham) or another one of the 3 research assistants working with me. During the group discussion we will be working on a group activity. I will be providing picture cards to the group. These cards describe various concepts about cooking. As a group you will place the cards into one of four categories based on cooking fuel type. As we get further into our discussion I will explain the activity in more detail.

Risks:

Your participation in this study is limited to a 1 time conversation and you should endure no risks.

Benefits:

You may not benefit from this group discussion personally, however we hope information learnt from this group may benefit your community in the future.

Payment:

No monetary payment will be provided to research participants.

Confidentiality:

There may be several people associated with the study team including myself, research assistants, or other professors at Emory University that may have access to this group discussion. The research team for this project must abide by the ethics regulations and will not share any information from this discussion with others. All Emory University faculty and staff are also held by law to not discuss any information learnt. All things discussed in this meeting are to remain confidential. That means that you may not carry any information heard here outside of this group and tell others what people have said.

Are we all in agreement that what everyone says will remain confidential?

Thank you all for agreeing to keep information confidential. After our discussion I will take out all information from the discussion that involves identifying people, like names, schools, where you live.

Does anyone have any questions about confidentiality?

Recorder:

It will be important after the discussion is over that I am able to recall what is said in this group. In order to remember the discussion I would like to record this conversation. (Show group the recorder). The information recorded will be brought back to the United States and Emory University in a digital file.

The digital recorder will be locked with the researchers at all time, and no one will have access to the recorder except for the research team members. The Emory Institutional Review Board, a federally regulated institution that handles research with human subjects, does however have a right to review the records if necessary.

Is it ok with everyone that I use this digital recorder during our conversation?

Thank you for allowing me to use the recorder, and as we discussed before, everything will remain confidential.

Questions:

If you have any questions regarding this study please contact Megan Graham at (local number) or at mgraha4@emory.edu. If you have questions about human subject rights please contact the Emory Institutional Review Board at 001+404-712-0720 or Emory University, IRB, 1599 Clifton Road, 5th floor, Atlanta, GA 30322, USA.

Verbal Consent:

I am passing out an information sheet that you may keep for personal information. Please do not consent to participation in this study if you have not had a chance to ask questions or are unsure about your participation in any way.

Please ask me if you have any questions regarding the study.

If you are ready to give your consent we will do that at this time. Do I have everyone's consent (permission) to use the information you provide me today in my research? Thank you for your consent.

Continue on to Discussion:

Now that we have discussed the purpose of this study and your participation in the study, shall we move onto the discussion?