Clean cookstoves for improving women's health: initial findings from rural Uganda

Lila Kumar Khatiwada
Initiative for Global Development, University of Notre Dame

Abstract

Traditionally, households in rural Uganda depend on biomass-burning cookstoves for cooking. These cookstoves are regarded by many to be inefficient, because of the amount of firewood they require to operate, as well as their relatively long cook times. This study assesses the impacts of an intervention aimed at replacing inefficient cookstoves with fuel-efficient models in rural Uganda. The primary objective of this project was to improve the health of women in a number of households. A randomized controlled trial (RCT) method was applied in designing the study, where communities were put into treatment and control groups at random. Notre Dame Initiative for Global Development (NDIGD) staff collected baselines, midline, and endline data at three separate points throughout the duration of the project. This paper presents the results from midline survey.

We used simple descriptive statistics and mixed models in analyzing the results. We found that a greater number of people were using the new stoves for cooking; over 95 percent households were found to be using the clean cookstoves to prepare meals at the time of midline data collection. The results also showed that the villagers in treatment villages ultimately used less firewood in comparison to the control villages. This resulted in households in treatment villages spending slightly less time collecting firewood than households in control villages. Further, there were fewer cases of burn injuries in treatment villages compared to control villages. Respondents using clean cookstoves also reported that it took less time to cook several foods. Additionally, the level of indoor carbon monoxide (CO) decreased in treatment villages compared to the control villages, which resulted in a lower number of smoke-related health issues for women. While these results are encouraging, it will be vital to ensure the sustainability of project so that the positive impacts can last longer.

Introduction

Rural households in Uganda depend on biomass-burning cookstoves for cooking. Increased use of firewood for cooking increases the risk of smoke-related diseases (e.g., coughing, asthma, etc.) among women and children (Sota et al., 2013; Northcross, 2009). In recent years, there have been efforts to replace traditionally inefficient cookstoves with more efficient clean cookstoves, which burn less firewood and cook food quicker. Reducing the amount of fuel needed helps to reduce adverse environmental effects from traditional stoves (Burwen & Levine, 2012).

This paper documents the results of a field experiment in Uganda where rural households were provided with clean stoves with the goal of improving health. With funding from The Conrad Hilton Foundation, this program has been implemented in the Apac district of Uganda. The Apac district consists of three counties spread over 14 rural sub-counties and one town council. In total, there are 1,184 villages in these sub-counties and town council. The district had a population of 527,155 as of mid-2009. The majority (97.6 percent) of that population were in rural areas, while only 2.4 percent were urban-based (Apac District Statistical Abstract, 2009).

About 97 percent of the population in rural Apac used firewood in their traditional stoves as the main source of cooking (Apac District Statistical Abstract, 2009). This new intervention aims to replace inefficient cookstoves with fuel-efficient models and improve the health of women and children in the households in which the fuel-efficient models are used. Specifically, the project aims to:

1. Reduce individuals' exposure to air pollution produced by traditional stoves/fireplaces, thereby reducing the negative health effects.

2. Replace the use of traditional stove with more efficient clean stoves.

To evaluate the impact of cookstoves on indoor air pollution and health, we designed a cluster randomized control trial (RCT) study. The results from an RCT-based study are more credible than other types of studies and are more likely to be used to replicate and fund programs that are found to be effective.

The RCT is considered by many to be the "gold standard" for evaluation work. In RCT-based studies such as this one, the population is divided into a treatment and a control group. Individuals or communities are assigned to one of these two groups by a random process. This design produces an unbiased estimate of the effect of the intervention (with higher internal validity). In this design, researchers randomly assigned 35 villages to have clean cookstoves, in addition to basic water and sanitation components, while another 35 villages received only the water and sanitation components of the program. In each village, researchers followed six households over the period of study.

Researchers completed a baseline study in 2014, which gathered information on the number of cookstoves/fireplaces currently used by the villages, including information on: the frequency of use in households, time involved to prepare various meals, firewood collection time, health issues and doctors visits, and indoor carbon monoxide (CO) levels. This paper presents the findings of midline data collection, which was done in April 2016.

Cookstoves and Health: Literature Review

Studies conducted in numerous geographical locations have documented the detrimental effect of smoke on human health that comes directly from burning firewood (Bruce at al., 2000; CREEC, 2011; Grabow et al., 2013). High levels of carbon monoxide and particulate matters (PM) smaller than 2.5 micron are understood to contribute directly to several health issues within households that burn firewood. The particulate matters enter the bloodstream through the lungs and have the potential to cause premature death in children. Yet, the significance of the health effects caused by exposure to indoor air pollution and the increased risk of acute respiratory infections in childhood, chronic obstructive pulmonary disease, and lung cancer have been somewhat neglected by the research community and policy makers in developing countries (Bruce at al., 2000). However, in recent years there has been an effort to address this problem by replacing traditional stoves with efficient clean cookstoves.

Examining the impact of clean cookstoves in health has produced encouraging results in household settings. In a study in Ghana led by Burwen & Levine (2012), it was found that women in the treatment group, who received improved cookstoves, self-reported far fewer symptoms related to cooking and respiratory symptoms than the women in the control groups, who did not receive cookstoves. The proportion of women reporting eye irritation was significantly lower in the treatment group than the control group in all follow-up periods.

In another instance, the prevalence of reported headaches were also lower for women in households with new cookstoves, but these differences were only significant for 18 months (Diaz et al., 2007). The likelihood of having sore eyes was substantially reduced in the treatment group relative to the control group cooking with an open fire during all of the follow-up periods. Their study confirmed that the use of the clean cookstoves in this population significantly reduced exposure to indoor air pollutants, as indicated by CO levels in the breath, the prevalence of sore eyes, and headaches over an 18-month period (Diaz et al., 2007). Duflo et al. (2008) found that using a clean cookstoves was associated with a lower probability of having a cold or flu, a cough, or a serious cough in the last 30 days in India.

Using improved cookstoves also reduces the amount of firewood for cooking, which translates into a lower concentration of dangerous gases inside the house. In a study, Rosa et al. (2014) found that the overall mean and median over 24-h $PM_{2.5}$ concentrations in intervention households were much lower in treatment households when compared the to control in Rwanda. The researchers documented a 48 percent reduction in median 24-h concentrations in program households.

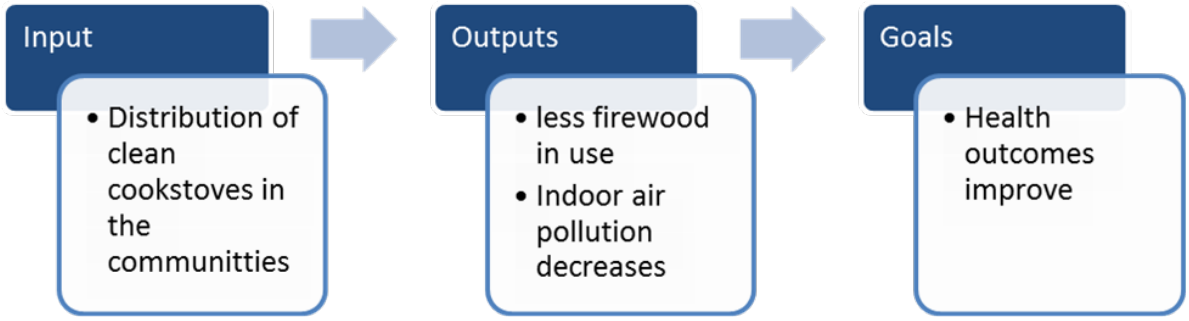
While there are studies that have found very promising results in improving the health of women and children in households in which clean cookstoves are used, not all interventions have produced desirable changes. For example, in Senegal and Gambia the clean cookstoves failed to reduce the concentration of hazardous emissions and there were no positive changes in the health of women and children (Sota et al., 2013). It is imperative to examine what the impacts of clean cookstoves are in the case of Uganda.

Theory of Change

The use of traditional cookstoves and solid fuels increases indoor air pollution. People have been using inefficient cookstoves because clean and efficient stoves are not available in rural areas. By providing clean cookstoves to replace the old inefficient cookstoves, the aim is to reduce indoor pollution and improve the health of household members.

By continuously using traditional cookstoves, people constantly inhale and expose themselves to high levels of smoke. This continuous exposure is said to be the main cause of many smoke related illnesses, including coughing, asthma, eye irritation, lung infection, etc.

The introduction of efficient clean cookstoves has reduced the amount of smoke of which the person preparing the food and other members of the household inhale. This decrease in exposure to smoke will improve the health conditions of the household and lead to a decrease in smoke related illnesses such as asthma and lung infections, and improve the overall health of all household members. The following graphic depicts how the introduction of efficient cookstoves will lead to better health outcomes.



Uganda Study

Broadly, the impact evaluation of cookstoves is divided into two parts: one seeks to establish the efficiency of the cookstoves, whereas the second attempts to measure the health effects of reduced exposure to harmful particles released with traditional cookstoves that use solid fuel.

While there have been many rigorous studies establishing that clean cookstoves are more efficient and produce less harmful gasses, the second part of our evaluation, measuring health effects, is scarce. To our knowledge, only a few RCTs exist that have evaluated the impact of clean cookstoves on health. One RCT was carried out by the University of California-Berkeley in Guatemala, which measured the effect of air pollution on chronic health issues in early childhood. A cohort of children was followed over five years to determine health effects on lung and cognitive development. The study found some positive impacts of clean cookstoves on health. Hanna et al. (2012) did a large scale study looking at the health and environmental effects of improved cookstoves in India. This RCT-based evaluation found no evidence of improvement in lung functioning or health. Unfortunately, the study also could not find any change in overall fuel consumption.

This project aims to add to the body of knowledge concerning health effects and cookstoves using the gold standard methodology in program evaluation in Uganda. In addition, the location of this project in Uganda will be more relevant to understanding the effect of air pollution produced by cookstoves in the sub-Sahara region, where culture and housing is different to the Guatemalan or Indian context.

During the evaluation, researchers conduct household surveys at three different points: before the project start (baseline), at midline, and endline. This allows researchers to track changes, measure the impact of the project, and determine whether the changes are likely to increase over time. The design of this study allows us to detect at least an effect size of 0.4, with a 95 percent of confidence (Type I error) and a power of 80 percent (Type II error).

Sample Selection

Researchers employed a two-stage sampling procedure to select the households for this longitudinal study. Researchers randomized villages and households to avoid selection bias.

➔ Assigning villages randomly to “treatment” and “control”

- 35 villages to treatment, and
- 35 villages to control

➔ Selecting 6 households from the list in a village for the survey

For household data collection researchers selected 35 program villages, termed as “treatment villages,” randomly from the list prepared by International Lifeline Fund (ILF), a partner organization of the Notre Dame Initiative for Global Development (NDIGD). ILF provided the researchers with a list of 83 possible villages from 10 sub-counties of the Apac district for randomization. Researchers also selected 35 control villages randomly for control group purposes. In this study there are a total of 420 households for survey. We believe that our research design is the best method for measuring impact because it allows for estimating what would have happened if there was no intervention (counterfactual). Provision of a counterfactual is essential for establishing causality. Without it, we have no way of knowing whether changes in outcome of interest are caused by the intervention, by chance, or by other factors.

Data Collection

The survey was conducted by local enumerators who were trained for three days. The training program was focused on providing enumerators with the necessary skills and techniques for conducting surveys using smartphones. We prepared our questionnaire on the Open Data Kit (ODK) platform and uploaded the survey to smartphones running Android software. The enumerators practiced the survey several times before they felt comfortable conducting the survey. During the training, the enumerators were given a chance to conduct the survey with women by asking questions related to cooking, stove use, smoke-related illness, doctor visits, fuel use, and food preparation. This provided an opportunity to pilot the survey and test the relevancy of each question.

Further, researchers used Dositubes to measure indoor air pollution and personal exposure to carbon monoxide (CO). This approach allows us to measure the changes in the self-reported health status of household members and correlate them to illnesses that are associated with indoor air pollution. Self-reporting has been used for evaluation and offers an inexpensive solution in measuring health benefits.

Researchers monitored the exposure of one member of the household to CO during the data collection. We visited each household one day in advance to place the device, which requires 24 hours to measure exposure. After receiving permission from the primary cook in the household, the Dositube was clipped to the cook's clothing and they were asked to wear it this way for 24 hours (see pictures, below) for monitoring CO personal exposure. This person carried a color diffusion tube (Dosimeters tube) for about 24 hours. These tubes have a compound that changes color when exposed to CO. The tubes give a weighted average exposure to CO by matching the color change.

Picture: Dositube showing CO level (dark line along the tube)

Quality control

As previously mentioned, researchers first trained the enumerators on using smartphones in local languages for data collection. Great attention was paid to quality control measures. We supervised data collection work constantly during the data collection phase, and made sure to provide more rigorous oversight at the beginning of survey to discover any issues with data collection, sampling, or timing. We then reviewed the data when uploaded in the server for completeness. On average, it took 30 minutes to complete a survey.

A woman in her kitchen with a Dositube in a treatment village

After the survey, the data was uploaded to the ODK platform and later downloaded as a comma-separated values (CSV) file for analysis.

Results

Cookstoves Distribution and Usage

ILF reports that it has distributed over 3,000 clean cookstoves in the study areas. Researchers conducted the survey in 420 households, including 201 households with ILF's clean cookstoves. On days that interviewers visited households, over 97 percent of respondents reported that they had used the clean cookstoves in preparing that day's meal. This indicates that the cookstoves were being used at high rates within the households. The average number of clean cookstoves in household was 1.7, with a maximum of three. Most of the cookstoves were distributed between the months of August and December 2015. Over 90 percent of respondents in treatment villages reported that they received training on how to set up and maintain the cookstoves.

Descriptive Statistics

To understand the present socioeconomic background of households, type and frequency of meals they prepare, types of cookstoves they use, fuel use, health issues, and personal exposure to CO level, some descriptive statistics were computed. The results are presented by comparing treatment and control villages so that it is easier to see the differences between the villages.

Socioeconomic

The mean age of respondents (women who cook everyday) in the treatment villages and the control villages was 40 years (Table 1). On average, the number of children in treatment villages was 3.6, while there were 4.28 in control villages.

With regard to the respondents' educational background, in treatment villages 25 percent had no schooling, 64 percent had primary level, seven percent had junior high school, and three percent had senior high school. In control villages, 34 percent had no schooling, 58 percent had primary level, one percent had junior high school, and one percent had senior high school.

Researchers also documented the assets that each household had in the treatment and control villages, finding nearly identical patterns. For example, radio possession (66 percent vs. 60 percent), mobile phone possession (60 percent vs. 60 percent), bicycle possession (83 percent vs.

83 percent), motorcycle possession (13 percent vs. 13 percent), television possession (2 percent vs. 2 percent), generator possession (1 percent vs 1 percent), and electric torch possession (56 percent vs. 56 percent) were at mostly consistent levels.

Further, researchers documented households' cash income in the last month in both treatment and control villages, although self-reported income is prone to be underreported or exaggerated. On average, households in treatment earned UGX 70,000 in the last month (roughly US$20) while in control villages, the households earned a slightly lower amount, UGX 67,000 (US$19) in the last month.

Table 1. Values of some socioeconomic indicators in control and treatment villages

Variables	Treatment villages	Control villages
Mean age of women	40	40
Average number of kids	3.6	4.28
Schooling (*in percent*)		
No school	25	34
Primary school	64	58
Junior high school	7	1
Senior high school	3	1
Households Assets (*in percent*)		
Radio	66	60
Mobile Phone	60	60
Bicycle	83	83
TV	2	2
Generator	1	1
Electric torch	56	56
Household average cash income last month (UGX)	70,000	67,000

Stoves/Fireplace Use

Both treatment and control villages had a similar average number of stoves/fireplaces in the households, with an average of 1.8, and as many as 3 in some households. Over sixty percent of households in both treatment and control villages had three stone fireplaces. Over 97 percent of households in treatment and 95 percent households in control had a fireplace outside of the household to boil water and prepare some beverages. The average number of days the cookstoves were used was 6.7 days in treatment and 6.6 days in control in the last seven days.

Researchers also found differences in burn injuries. In treatment households, about two percent of households reported burn injuries from open fires in the last month. But in control households the incidence of burn injuries was higher, about 16 percent. Households with clean cookstoves have fewer incidences of burns, which can be attributed to clean cookstoves, which shows that clean cookstoves are safer to operate.

A typical hut that houses a kitchen in Apac, Uganda

Food and Preparation Time

The Apac people have a moderately varied diet. Common foods prepared in Apac are posho, cassava, sweet potatoes, beans, rice, porridge, pigeon pea, meat, fish, and boo (Table 2). Our survey included these food items. We specifically asked how much time it takes, on average, for each food preparation. Aggregating response for cooking time, we obtained the following results in treatment and control villages:

Table 2. Food preparation time

Food items	Average minutes in treatment	Average minutes in control
Posho	25.84	27.71
Cassava	49.00	50.44
Sweet potato	48.77	45.06
Beans	124.93	134.68
Rice	26.99	28.41
Porridge	19.35	18.55
Pigeon pea	137.43	123.73
Meat and fish	69.12	72.96
Boo	27.07	25.18

The results show that households in the treatment villages spent less time cooking most of the food. However, for some foods like sweet potato, pigeon pea, and boo, treatment households needed slightly more time.

Firewood Collection and Use

Of those who collected firewood on their own from the farm and forest, 120 minutes were spent on average doing so in treatment villages and about 130 minutes in control villages when they went to collect firewood last time. Researchers found that the control villages took slightly longer to collect firewood than the treatment villages. This might be because the control households are still using traditional stoves, which require more firewood than the improved one. On average, the collected wood lasted approximately seven days in treatment and five days in control villages. This indicates that the clean cookstoves are more efficient and consume less firewood so the collected firewood lasted longer in treatment villages.

Exposure to CO

Personal exposure to carbon monoxide (CO) is higher than the threshold level in control villages. The World Health Organization (WHO) suggests a 24-hour mean for CO is 7 mg/m3. In treatment villages researchers found the CO level was 6.7 mg/m3, and in control villages it was 13.15 mg/m3. Researchers also found that a higher level of CO concentration was correlated with using traditional stoves/fireplaces for cooking in households. While this is not surprising, this suggests that using traditional fireplaces/stoves increases the level of CO inside the households.

This result is interesting from a programming perspective as researchers were able to document the positive impact of clean cookstoves in reducing CO exposure in the households. This may lead to a reduced number of health issues in the treatment villages.

Health Issues

Researchers asked women questions related to smoke-related health issues. Results of various health issues, based on self-reported responses, are presented below.

The respondents reported a number of health concerns related to indoor pollution. In the questionnaire, researchers listed common health issues related to indoor air pollution, such as irritated eyes, headache, cough, sore throat, bad cough, shortness of breath, heavy chest, and bad cough with mucus.

In treatment villages, nearly two-thirds of respondents did not experience irritated eyes even a single day in the week prior to taking the survey; about 33 percent had at least one day of irritated eyes in the week prior to taking the survey. Researchers found different patterns in control villages as about 80 percent had irritated eyes for at least one day, and over 37 percent had irritated eyes for all seven days in the week prior to taking the survey, which is higher than in treatment villages.

Regarding headaches, about 77 percent of respondents in the treatment villages reported that they did not experience headaches in the week prior to taking the survey. That means only about a quarter experienced a headache for at least one day that week. However, in control villages, 76 percent reported that they had a headache at least one day during the week prior to taking the survey, and about 23 percent had a headache for all seven days.

In the treatment villages, about 20 percent of respondents had a cough for at least one day during the week prior to taking the survey and only about three percent reported they had a cough on all seven days. In control villages, researchers found that 50 percent of respondents had a cough for at least one day in the week prior to the survey and about 18 percent had a cough all seven days. This is an interesting finding as we were able to directly to observe that the clean cookstoves were able to reduce exposure to smoke and coughing.

Researchers also asked respondents if they had a sore throat, bad cough, shortness of breath, heavy chest, or bad cough with mucus in the week prior to the survey. In treatment villages, about eight percent had a sore throat, eleven percent had a bad cough, seven percent had shortness of breath, eight percent had a heavy chest, and five percent had a cough with mucus. We found different patterns for these illnesses in control villages as about 24 percent had a sore throat, 17 percent had a bad cough, 28 percent had shortness of breath, 35 percent had a heavy chest, and 15 percent had a cough with mucus. All these indicate that after the introduction of clean cookstoves people are experiencing fewer cases of smoke-related illnesses in treatment villages.

Additionally, researchers asked villagers if they visited doctors or health centers for these types of illnesses. In treatment villages, about 28 percent of respondents mentioned that they visited a

doctor at least once in the previous year because of cough, eight percent visited at least once for shortness of breath, about 30 percent for irritated eyes, and about 18 percent for chest pain.

Researchers found different patterns in control villages as about 30 percent of respondents mentioned that they visited a doctor at least once in the previous year because of cough, 12 percent visited at least once for shortness of breath, about 30 percent for irritated eyes, and about 18 percent for chest pain.

It is interesting to note that there are fewer numbers of doctor visits because of smoke-related illness in treatment villages compared to control. While households in the treatment villages received their new cookstoves recently (most of them received in the last six month at the time of survey), researchers anticipate that overall health will be far better in treatment villages if villagers continuously use clean cookstoves for cooking in the future.

Impact Estimates

To estimate the impacts of various indicators in control and treatment villages researchers used a mixed model approach. Mixed models analyze results from repeated design measures in which the outcome is continuous and measured at a fixed period of time. In this study researchers measured various indicators repeatedly. For example, the level of exposure to CO or the time it takes to cook various foods.

Mixed models handle a hierarchy of levels with the repeated, correlated measurement occurring among all of the lower level units for each particular upper level unit. In this study, households are nested within the villages and the villages are nested within the control and treatment groups. Using a mixed model, researchers can estimate the changes within the cluster and between the clusters over a period of time.

The results of the differences between treatment and control villages for various indicators are presented below (Table 3).

The results show that bean cooking time is significantly lower in treatment villages than in control villages. Most of the health-related indicators are better in treatment villages than in control villages as the respondents experienced fewer days of irritated eyes, headache, coughing, sore throat, shortness of breath, heavy chest, and cough with mucus in treatment villages. One of the reasons for having household members with fewer health issues is that the level of indoor Carbon Monoxide (CO) was much lower in the treatment than in the control.

Table 3. Mixed model results

Indicators	Coefficient	Std Error
Time to cook (self-reported, in minutes)		
Posho	-1.20	3.26
Cassava	-0.63	3.10
Sweet potatoes	0.53	2.91
Beans	32.04***	8.24
Rice	-0.66	2.06
Porridge	0.57	1.60
Pigeon pea	10.79	11.79
Meat/fish	1.63	5.92
Boo	0.29	3.02
Time to collect firewood	0.77	3.26
Number of days firewood lasted	0.618	1.44
Self-reported health issues (women)		
Days irritated eyes	2.82***	0.24
Headache	2.36***	0.22
Days coughing	1.16*	0.50
Sore throat	0.15***	0.03
Bad cough	0.04	0.03
Short breathing	0.21***	0.37
Heavy chest	0.28*	0.03
Cough with mucus	0.10**	0.03
CO level	6.80***	1.58

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Conclusion and Recommendations

Overall, researchers found many positive impacts, which were a result of the introduction of clean cookstoves in the villages. Women benefit most from these cookstoves as they enable them to spend less time collecting firewood and cooking food. Indoor air pollution levels are also improved, which is positively translated into fewer health issues.

There was a greater use of new stoves for cooking. This indicates that there is high uptake, which is not common elsewhere. The descriptive statistics show that households spent slightly less time collecting firewood in treatment villages than that in control ones, demonstrating that there was a reduction in the amount of firewood used. The women save some time that can be used for other household activities. There were fewer cases of burn injuries in treatment villages compared to control. Using clean cookstoves, respondents reported that it took less time to cook several foods. Compared to control villages, treatment households also had a lower number of smoke-related health issues which led to fewer doctors' visits and saving money for doctors' fees and medicine. Also, households experienced a reduced level of indoor CO in treatment villages compared to control. Further, the mixed model also confirmed these improvements in the households.

All of these results are promising. However, one challenge for maintaining these results is that villagers may discontinue using clean cookstoves over time. It is important to monitor and address

any issues with the stoves, such as malfunction. In addition, it is also important to encourage villagers to use the stoves continuously by making visits to the households.

Large households may continue to use traditional stoves if they are only provided with a single improved cookstove, as having access to only one stove might slow the cooking process. Large households should be provided with multiple cookstoves.

Sustainability is a significant concern as the villagers are likely to revert to using traditional stoves if their clean cookstoves break and they are unable to fix them. Providing training on how to perform basic maintenance could also help to keep the stoves functioning and keep villagers using the clean cookstoves.

The distribution of stoves has just been completed in some villages at the time of the midline survey. It will be important to know how those people use the clean stoves in the coming days. The endline survey, scheduled for early 2017, may capture the long-term impact of clean cookstoves.

References

Bruce, N., Perez-Padilla, R., & Albalak, R. (2000). Indoor air pollution in developing countries: a major environmental and public health challenge. *Bulletin of the World Health Organization*, 78 (9).

Burwen, J., & Levine, D. (2012). A rapid assessment randomized-controlled trial of improved cookstoves in rural Ghana. *Energy for Sustainable Development,* 16: 328-338.

CREEC. 2011. Northern Uganda Energy Study. Centre for Research in Energy and Energy Conservation College of Engineering, Design, Art and Technology, Makerere University, P.O. Box 7062, Kampala, Uganda

Diaz, E., Smith-Sivertsen, T., Pope, D., Lie, R., Díaz, A., McCracken, J., Arana, B., Smith, K., & Bruce, N. (2007). Eye discomfort, headache and back pain among Mayan Guatemalan women taking part in a randomized stove intervention trial. *J. Epidemiol. Community Health* 2007;61;74-79

Duflo, E., Greenstone, M., & Hanna, R. (2008). Cooking stoves, indoor air pollution and respiratory health in Rural Orissa. *Economic and Political Weekly*, 43(32): 71-76.

Grabow, K., Still, D., & Bentson, S. (2013). Test Kitchen studies of indoor air pollution from biomass cookstoves. *Energy for Sustainable Development*, 17(5): 458–462.

Hanna, R., Duflo, E., & Greenstone, M. (2012). Up in smoke: The influence of household behavior on the long-run impact of improved cooking stove. *MIT Dept. of Economics Working Paper Series*: 12-10.

Higher Local Government Statistical Abstract. 2009. Apac District. P.O Box 1, Apac-Uganda.

Northcross, A., Chowdhury, Z., McCracken, J., Canuz, E., & Smith, K. (2010). Estimating personal PM2.5 exposures using CO measurements in Guatemalan households cooking with wood fuel. *Journal of Environmental Monitoring,* 12(4):873-8.

Rosa, G., Majorin, F., Boisson, S., Barstow, C., Johnson, M., et al. (2014). Assessing the impact of water filters and improved cook stoves on drinking water quality and household air pollution: A randomised controlled trial in Rwanda. *PLoS ONE* 9(3): doi:10.1371/journal.pone.0091011

Sota, C., Lumbreras, J., Mazorra, J., Narros, A., Fernández, L. & Borge, R. (2014). Effectiveness of Improved Cookstoves to Reduce Indoor Air Pollution in Developing Countries. The Case of the Cassamance Natural Subregion, Western Africa. *Journal of Geoscience and Environment Protection*, 2, 1-5. doi: 10.4236/gep.2014.21001.

World Health Organization (WHO). Indoor air pollution and household energy. Available at: http://www.who.int/heli/risks/indoorair/indoorair/en/