Indoor Air Pollution Monitoring Summary

for

The Gaia Association CleanCook Stove Tests in the Kebribeyah Refugee Camp, Somali Regional State, Ethiopia

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and

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Purpose of Study

Under the guidance of the Center for Entrepreneurship in International Health and Development (CEIHD), Gaia Association has performed indoor air pollution (IAP) tests for the past year in homes in Addis Ababa and refugee camps throughout Ethiopia. IAP in refugee communities is a major concern, and the data collected from this study will aid in the mitigation of the negative effects of indoor smoke. CEIHD is assisting with the air quality measurements and equipment in pilot study homes and will use data generated by this study.

Background of Gaia Association and This Study

Gaia Association is an Ethiopian NGO formed one year ago to further the aims of Project Gaia Research Studies, which has as its purpose to demonstrate the use of alcohol fuels (ethanol and methanol) for household and refugee use in Ethiopia. The association seeks to replace existing traditional fuels such as firewood, kerosene, charcoal, and dung that have been shown to be harmful to human health. The vehicle for this change is the CleanCook stove by Dometic AB, which is fueled by ethanol.

For the past year, Gaia has been collaborating with UNHCR (The United Nations High Commission for Refugees) and ARRA (Administration of Refugee and Returnee Affairs) to distribute the CleanCook stove to the Kebribeyah refugee camp, which is located in the eastern Somali Regional State. Since the project's inception 800+ stoves (households) along with 10 liters (a 10 day supply) of ethanol have been distributed to each participating household. In the future, the program will expand to include all homes inside the camp. In order to ensure a sustainable fuel supply, an ethanol storage facility has been built at Kebribeyah. The storage facility can hold up to 16,000 liters of ethanol and the association has also secured a tanker to transport the ethanol from FINCHAA (an ethanol distillery) to Kebribeyah.

Kebribeyah currently accommodates over 16,000 refugees. The camp conditions and construction of the refugees' structures contribute to high levels of IAP. Entrances to homes are the only access to fresh air, and most homes/cooking areas are poorly ventilated. Predominant use of solid biomass cooking stoves indoors and the lack of ventilation results in high levels of indoor air pollution, such as carbon monoxide (CO) and particulate matter of aerodynamic diameter less than or equal to 2.5 microns ($PM_{2.5}$). Use of incense and kerosene for lighting also add to high levels of CO and $PM_{2.5}$ in the indoor air. The close proximity of the homes contributes to transference of PM and CO from one house to another. The dry, arid, and windy climate of the eastern region also plays a part in the levels of outdoor air pollution.

The project provided an opportunity for the participants and residents of the camp to gain firsthand knowledge about IAP and to learn that it is a major human health concern. Through the assistance of interpreters, several issues were addressed regarding the study and the subject of IAP. The participants were extremely concerned about how IAP affected their lives, and they expressed varied health concerns regarding the issue. The information collected at Kebribeyah provided evidence not only to our team, but also most importantly to the stakeholders, that alternative fuels and technologies have their place in refugee communities. At the completion of the study, the participants knew that the equipment placed in their homes would contribute to data that in the future would aid them and their living conditions. By conducting the study, we gave legitimacy to the stakeholders' concerns that IAP has negatively impacted their health and livelihoods. The stakeholders reported the positive effects of the CleanCook and how it mitigated the negative effects of IAP.

Special Conditions of the Camp

The Kebribeyah refugee camp offers an exceptional testing environment, because the homes are uniform through out the community. All are characterized by their lack of good ventilation. Homes and cooking shelters alike have doors covered by cloth flaps and no windows.

Due to the political instability in the region, it was imperative for the Gaia Association IAP team to leave the camp by 17:00 everyday.

Methods

The study was conducted in a total of 11 households in Kebribeyah Camp. The format of the study consisted of monitoring indoor air quality in homes for 48 hours both before and after the introduction of the CleanCook stove. Monitoring equipment was positioned in kitchens in accordance with the standard placement protocols given by CEIHD.

The requirements were:

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

The devices were placed for a 48 hr period in accordance with the above requirements. After the devices were placed in the refugee camp households, sketches were made of the placement of the equipment and the kitchen and photographs were taken.

The CO concentrations in the room were measured with the HOBO CO logger (model # H11-001, Onset Computer Corporation, Bourne, MA, USA), which was set to record a concentration reading every minute. Fine particulate matter was measured by the University California Berkeley Particle Monitor (UCB PM), which uses a photoelectric detector (Litton et al., 2004; Edwards et al., 2006). The UCB PM measured the $PM_{2.5}$ concentration every minute (reported in units of milligrams per cubic meter of air, mg/m^3). Color dosimeter tubes (model # 1DL, Gastec Corporation, Kanagawa, Japan) were also used to measure CO. The Gastec CO tube offered a different, simpler method of measuring the CO levels.

Six HOBO CO loggers were used in the study. These loggers were purchased by Gaia Association and calibrated at the Indoor Air Pollution Lab at the University of California-Berkeley using CO standard gas of 5 and 60 ppm. Before the start of the 'Before' and 'After' sampling, a co-location calibration check was performed in the Gaia Association office kitchen to test whether or not the six HOBO loggers were working properly. The six HOBO loggers were tested against a seventh HOBO logger which was called the "Gold Standard" (and was not otherwise used). This protocol was followed after each of the devices was used six times.

The Gastec CO tube yields one average CO concentration. Each tube was read inside the households at the 24 hr and 48 hr marks.

The UCB particle monitors were produced and calibrated in the IAP Lab at UC-Berkeley before they were used in the refugee camp in Kebribeyah. The photoelectric chamber of each of the devices was cleaned with isopropyl alcohol after every five uses.

The above monitoring equipment was launched and downloaded on the premises of the camp. The data was then organized and analyzed at the Gaia Association office in Addis Ababa.

Pre and Post–Monitoring Questionnaires

A pre-monitoring questionnaire was used to measure the structure of the cooking areas. At the end of the 48 hr testing period, a post-monitoring questionnaire was administered to the 11 participating households. Also at this time, the monitoring equipment was taken down and end times recorded.

During the post-monitoring questionnaire, the main cook of each household was asked a series of questions to determine what the household conditions were like throughout the monitoring period. The questionnaire contained a total of 39 questions. These questions were designed to help interpret the IAP data collected during the 48 hr period. Questions such as what type of fuel was used and for how long the participating family cooked help explain why there may have been higher or lower levels of CO and PM recorded during the study.

Household Selection

The refugees at Kebribeyah Camp have uniform living conditions. The conditions of the homes and the type of stoves and fuels used do not vary.

Before the field team departed for Kebribeyah, the requirements of the study were sent to the ARRA headquarters to aid in the selection of households. The refugee committee leader of zone four, section two (Farah Sahal) was selected to help facilitate this study. When the field team arrived they were met by an interpreter who communicated their expectations and goals of the project to the 11 selected households in this zone (from Amharic to Somali). The committee leader also accompanied the team to each household and explained in detail the functionality of the equipment and the requirements of the study. The questions of the participants were addressed at this time.

Consumer acceptance of the stoves, even for families with no previous experience with a modern stove and improved fuel, was very strong. Satisfaction with the cleanliness and safety of the stove was a common theme. The power of the stove also received uniformly high marks.

Results

Indoor Air pollution Concentrations

The following results are for the 48-hour concentration measurements of $PM_{2.5}$ and CO in Kebribeyah Refugee Camp kitchens. The 11 households selected for the study used a modified traditional wood stove as their primary stove and a metal charcoal stove as their secondary stove (Table 1). In the After Study (AS), the CleanCook stove was introduced (Table 2).

In addition to the mean, minimum, and maximum PM concentrations recorded during each monitoring period, the UCB PM software calculated the highest, second highest, and third highest 15-minute average PM concentration. Each of these three metrics is a consecutive 15-minute period, and none of the three periods overlap. All values are displayed in Tables 1 and 2.

Table 1. Results of the 48-hour kitchen concentration measurements of $PM_{2.5}$ and CO in 11 households using modified wood stoves and charcoal stoves (Before).

HH ID	$PM_{2.5}$ Concentration (mg/m^3)							CO (ppm)		
	# of records	Mean	Min	Max	Highest 15-min Ave	2nd Highest 15-min Ave	3rd Highest 15-Min Ave	HOBO Mean	HOBO Max	Tube Mean
Keb001	2892	2.19	0.03	77.88	60.87	45.37	39.13	77.0	645.0	>28.1
Keb002	2881	0.68	0.06	35.61	17.70	10.49	8.05	51.6	324.0	>26.5
Keb003	2881	2.77	0.03	75.49	40.12	38.53	35.45	117.2	707.0	>31.4
Keb004	2891	0.20	0.04	49.90	22.35	1.16	0.92	30.2	278.3	>28.1
Keb005	2879	2.40	0.03	76.71	66.92	57.48	48.99	83.6	637.0	>30.6
Keb006	2870	1.05	0.04	76.41	17.46	13.09	12.05	73.8	590.0	>28.1
Keb007	2715	0.66	0.03	77.05	32.78	26.61	9.16	54.0	551.0	>47.0
Keb008	2551	1.13	0.05	70.66	29.25	20.31	15.20	23.6	270.5	>47.0
Keb009	2741	4.10	0.03	75.48	64.65	59.45	58.25	54.0	454.1	>47.0
Keb010	2589	5.45	0.04	78.40	76.89	68.14	65.98	156.8	707.0	>47.0
Keb011	2736	3.20	0.03	77.62	40.97	38.44	35.02	53.7	438.5	>47.0

Table 2. Results of the 48-hour kitchen concentration measurements of $PM_{2.5}$ and CO in the same 11 households using the CleanCook stove (After).

HH ID	$PM_{2.5}$ Concentration (mg/m^3)							CO (ppm)		
	# of records	Mean	Min	Max	Highest 15-min Ave	2nd Highest 15-min Ave	3rd Highest 15-Min Ave	HOBO Mean	HOBO Max	Tube Mean
Keb001	2731	0.16	0.10	7.39	2.35	2.02	1.67	15.9	168.9	13.8
Keb002	2706	0.11	0.02	13.91	2.61	2.55	2.20	6.2	116.0	5.2
Keb003	2730	0.11	0.05	10.96	2.62	1.09	1.07	8.5	63.2	6.6
Keb004	2671	0.05	0.04	2.40	0.60	0.19	0.19	4.9	85.7	6.2
Keb005	2694	0.21	0.04	17.74	10.54	7.05	5.25	18.4	105.2	18.9
Keb006	2689	0.22	0.08	32.51	7.27	2.36	2.15	16.5	161.1	19.3
Keb007	2800	0.28	0.08	24.93	10.57	10.18	6.39	16.9	182.6	11.9
Keb008	2792	0.12	0.04	8.23	2.38	2.06	1.40	9.8	107.2	4.8
Keb009	2786	0.08	0.06	1.09	0.36	0.36	0.34	29.5	192.4	>24.3
Keb010	2768	0.05	0.04	1.31	0.33	0.24	0.24	26.8	268.6	>24.5
Keb011	2780	0.06	0.04	2.66	0.41	0.34	0.20	7.2	94.5	4.4

Table 3 shows the means of the PM and CO data for the 11 households in the Before and After monitoring, along with the standard deviations. The percent differences are also shown, comparing the Before and After averages (the Before values were used as the denominator).

Table 3. Average Kitchen Concentration and Percent Changes

	Before, Average	Before, Std Dev	After, Average	After, Std Dev	Percent change
PM: Average (mg/m^3)	2.17	1.63	0.13	0.08	-94%
PM: Minimum (mg/m^3)	0.04	0.01	0.06	0.02	+53%
PM: Maximum (mg/m^3)	70.11	14.05	11.20	10.33	-84%
PM: Highest 15-min ave	42.72	21.29	3.64	3.94	-91%
PM: 2nd Highest 15-min ave	34.46	22.00	2.58	3.19	-93%
PM: 3rd Highest 15-min ave	29.83	22.12	1.92	2.09	-94%
CO: Mean, HOBO (ppm)	70.5	38.6	14.6	8.2	-79%
CO: Maximum, HOBO (ppm)	509.3	165.5	140.5	60.1	-72%
CO: Mean, Tubes (ppm)	> 37.2	> 9.7	> 12.7	> 7.9	NA

The average of the set of 11 48-hour average kitchen $PM_{2.5}$ concentrations went down from 2.17 mg/m^3 in the Before (traditional wood stove) phase to 0.13 mg/m^3 in the After phase, when the households were using the CC stove. This is a 94% reduction. A Wilcoxon Signed-Rank test showed that this difference was significant ($p = 0.004$), as did a Student's t-Test ($p = 0.002$). The average minimum $PM_{2.5}$ concentrations were 0.04 mg/m^3 in the Before phase and 0.06 mg/m^3 in the After phase. The PM minimum average may be slightly higher in the After phase because of the dusty and windy conditions of the camp during that phase. The average maximum $PM_{2.5}$ concentrations dropped by 84% in the After sampling, relative to the Before phase. The highest, second highest, and third highest 15-minute average $PM_{2.5}$ concentrations were also significantly lower after the introduction of the CC stove, by 91 %, 93%, and 94%, respectively.

Similarly, the average 48-hour kitchen CO concentrations measured by the primary method, the HOBO CO logger, dropped from 70.5 ppm in the Before phase to 14.6 ppm in the after phase, a statistically significant reduction of 79% ($p = 0.004$ for the Wilcoxon Signed-Rank Test, and $p = 0.0004$ for the Student's t-Test). The average of the maximum CO concentrations was also significantly different (509.3 ppm Before versus 140.5 ppm After).

Post-Monitoring Questionnaire Results

The important findings of the Post-Monitoring Questionnaire are described below. The survey was administered to the main cook at the end of the monitoring session. Eleven of the 11 participants used a modified traditional wood stove for cooking during the Before sampling phase, while one household used a traditional three-stone wood fire stove. All 11 households used the CC stove during the After sampling phase. All households surveyed used a kerosene lamp for lighting on a daily basis in both the Before and After studies. The participants reported no cigarettes smoked during the study. Lastly, the number of people cooked for in each household was essentially the same in the Before and After phases (overall averages of 11.0 Before and 11.2 After). This is shown in Table 4 below.

Table 4. The number of people cooked for on the days of IAP sampling in the Before and After studies

HH ID	**Before, Number of people cooked for**	**After, Number of people cooked for**
Keb001	11	11
Keb002	12	12
Keb003	8	7
Keb004	8	8
Keb005	9	9
Keb006	10	12
Keb007	16	14
Keb008	11	11
Keb009	10	13
Keb010	11	11
Keb011	15	15
Average	*11.0*	*11.2*

Discussion

Comparison of Kitchen Concentrations to International Standards

The World Health Organization (WHO) sets air pollution guidelines to offer guidance in reducing the health impact of air pollution (both indoor and outdoor) based on current scientific evidence. The WHO recently set new Air Quality Guidelines (AQG) for $PM_{2.5}$, ozone, nitrogen dioxide, and sulfur dioxide, along with interim targets that are intended as incremental steps in a progressive reduction of air pollution in more polluted areas (WHO, 2005). The guideline for carbon monoxide was set in 2000 (WHO, 2000).

The results of the IAP monitoring in the 11 households are compared to the World Health Organization's AQG and interim target-1 (WHO, 2005) in Table 5 below. Note that the CO concentrations reported above in parts per million (ppm) were converted to mg/m^3 to match the unit used by WHO (by multiplying by the gram molecular weight of CO, 28, and dividing by the conversion factor of 24.45).

Table 5. Comparison of kitchen concentrations to WHO guidelines.

	Before (Modified traditional stove and Charcoal stove) (48- hr ave)	**After (CC stove) (48- hr ave)**	**WHO interim target-1**	**WHO Air Quality Guideline**
$PM_{2.5}$	2170 ug/m^3	130 ug/m^3	75 ug/m^3 (24-hr mean)[1]	25 ug/m^3 (24-hr ave)[1]
CO	80.7 mg/m^3	16.7 mg/m^3	NA	10 mg/m^3 (8hr ave)[2]

[1] WHO, 2005.
[2] WHO, 2000.

The average PM concentration in the kitchens was greatly reduced after the households began using the CC stove (from 2170 to 130 ug/m^3), a very significant improvement in indoor air quality. The households moved much closer to the WHO interim target-1 of 75ug/m^3 for $PM_{2.5}$ (and the Air Quality Guideline of 25 ug/m^3) in the After phase. The average CO kitchen concentration in the modified traditional stove and charcoal stove case was 80.7 mg/m^3 and dropped to 16.7 mg/m^3 during use of the CC stove, much closer to the WHO guideline of 10 mg/m^3.

Health Implications

The study on quantifying the human health impact of air pollution has evolved in the last several decades. The advancements in quantifying the effects are due to improvements in pollution monitoring, epidemiological studies, and statistical techniques. Large epidemiological studies have measured outdoor air pollution (primarily particulate mater) and impacts on the following health conditions: mortality, hospital admission for cardiovascular and respiratory disease, urgent care visits, asthma attacks, acute bronchitis, respiratory symptoms, and restrictions in activity (Ostro, 2004). As noted above, the WHO Quality Guidelines apply to both outdoor and indoor air.

These issues not only affect adults but also children under the age of five. Studies have shown that there is an association between ambient PM and infant mortality (Ostro WHO report, 2004). There is also an association between PM and low birth weight and premature delivery (Ostro WHO report, 2004) (Ritz et al, 2000). Both long and short-term exposure to IAP has detrimental effects on these populations.

Bart Ostro's 2004 World Health Organization publication also provided relative risk functions for four health outcomes. Table 6 below is reproduced from that report (Ostro, 2004) and shows the four outcomes and the associated exposure metric ($PM_{2.5}$ or PM_{10}), the functions (equations) themselves, including the suggested coefficients, the 95% confidence interval for that coefficient, and the subgroup to whom the outcome applies. The relative risk function allows one to quantify the risk of the outcome when people are exposed at one ambient (outdoor) PM concentration to the risk when they are exposed at another ambient PM concentration. This ratio of risks posed at the two different PM scenarios is called relative risk.

Table 6. Health outcomes and risk functions for air pollution exposure (reproduced from Ostro, 2004)

Outcome and exposure metric	**Source**	**Relative risk function**	**Suggested β coefficient (95% CI)**	**Subgroup**
All-cause mortality and short term exposure to PM_{10}	Meta-analysis and expert judgment	$RR = \exp[\beta\ (X-Xo)]$	0.0008 (0.0006, 0.0010)	All ages
Respiratory mortality and short term exposure to PM_{10}	Meta-analysis	$RR = \exp[\beta\ (X-Xo)]$	0.00166 (0.00034, 0.0030)	Age <5 years
Cardiopulmonary mortality and long-tern exposure to $PM_{2.5}$	Pope et al. (2002); R Burnett[a]	$RR = [(X+1)/(Xo+1)]^{\beta}$	0.015515 (0.0562, 0.2541)	Age >30 years
Lung cancer and long-term exposure to $PM_{2.5}$	Pope et al. (2002); R Burnett[a]	$RR = [(X+1)/(Xo+1)]^{\beta}$	0.23218 (0.08563, 0.37873)	Age >30 years

[a] Personal communication to the author of the original table (Ostro, 2004)

Though standard practice is to use these four relative risk functions for burden of disease calculations for populations exposed to outdoor air pollution, they can be applied, with much uncertainty, to individuals exposed to differing amounts of PM from either outdoor or indoor air. Here, the four relative risk functions were used to estimate the changes in health risk that result from the changes in kitchen $PM_{2.5}$ concentrations due to the introduction of the CleanCook stove. There were three major problems and sources of error in attempting this quantification of health risks.

The first is the problem of estimating the $PM_{2.5}$ exposure concentration of the household members, given only the kitchen concentrations. Personal monitoring was not performed in this study, no time-activity information was collected, nor did the household members spend their entire days in the kitchen where the monitoring occurred.

The second major problem is that the household members in this study were exposed, while in the kitchen during the Before sampling phase, to air pollution ($PM_{2.5}$) concentrations that exceeded the outdoor concentrations involved in the epidemiological studies upon which the relative risk functions are based. The shape of the concentration-response functions are not known at the high exposure concentrations involved in the Before study. Also, whether there is a threshold concentration, a concentration above which the risk no longer increases, for any of these health outcomes is still unknown.

The third and least troublesome problem in attempting to quantify the health risks associated with the changes in IAP seen in this study of the CleanCook stove is that the first two risk functions are based on PM_{10} concentrations, not $PM_{2.5}$ (PM_{10} stands for particles of aerodynamic diameter less than 10 microns). Fresh wood burning emissions are almost entirely made up of particles of less than 1.0 micron (Smith, 1987). Hence, this problem was addressed by assuming the PM_{10} concentration in the kitchens to equal the $PM_{2.5}$ measurements made. This is a conservative assumption in that the PM_{10} concentration can only be greater than that of $PM_{2.5}$.

To attempt to work around the first problem, data was pulled from studies that measured both kitchen and exposure concentrations for household members. A recent IAP monitoring study in Mexico that included kitchen concentration measurement methods similar to those used here (i.e. the same instruments and same placement criteria were used), but also measured the 24-hour personal PM exposure concentration, found that the ratio of the personal $PM_{2.5}$ exposure concentration of the main cook of the household to kitchen $PM_{2.5}$ concentration (the cook/kitchen ratio) to be 0.21 to 0.26 (Johnson et al., 2005). Bruce et al., 2004 showed child/kitchen concentration ratios ranging from 0.42 to 0.79 in rural Guatemala, which seemed to increase with increasing quality of the kitchens. That same trend was seen in a CEIHD study in Nicaragua (CEIHD, 2003) which found cook/kitchen concentration ratios of 0.56 and 0.73 for two groups using open fires and 0.79 and 0.92 for the same two groups when they upgraded to an improved stove with a chimney (the EcoStove). These three studies show the obvious, that the range in the ratio of personal exposure to kitchen concentrations is very large and dependent on the individual situation. Hence, attempting to assign such a ratio to a new situation, such as that in the Kebribeyah camp, is not particularly accurate and introduces much uncertainty. Nonetheless, a personal/kitchen concentration ratio of 0.50 was used here as the “best” estimate. A “high” personal exposure case of 0.80 and a “low” exposure case of 0.25 were also considered.

Multiplying the "Before" (traditional) kitchen $PM_{2.5}$ concentration average of 2170 ug/m^3 by the best estimate of 0.50 for the personal/kitchen concentration ratio yielded a personal exposure concentration estimate of 1085 ug/m^3. Similarly, the "After" (CleanCook) kitchen $PM_{2.5}$ average of 130 ug/m^3 led to an estimate of personal exposure concentration of 65 ug/m^3. These two exposure concentrations were applied to the risk functions in Table 6 to estimate the relative risks of going from the lower concentration scenario (CleanCook stove) to the higher concentration scenario (traditional). The same was done for the low personal exposure case (personal/kitchen = 0.25) and the high personal exposure case (=0.80). The resulting relative risk estimations are shown in the three columns on the left side of Table 7 below.

The right three columns of Table 7 show the estimated percent decrease in risk of each of the selected outcomes due to using the CleanCook stove versus using the traditional or modified traditional wood stove. The risk decrease fraction is equal to 1 – (1/RR). According to Table 7, the best estimate relative risk of all-cause mortality was 2.26 for the traditional (Before) versus the CleanCook (After) exposure cases of this study, which translated to an estimated 56% decrease in risk when going from the traditional to the CleanCook stove. Use of the CleanCook stove also had an estimated protective effect of a 82% reduced risk of respiratory mortality in children age <5 years (best estimate), a 35% lower risk of cardiopulmonary mortality in adults >30 years (for all three exposure cases), and a 48% reduced risk of lung cancer (all three cases) compared to use of the traditional wood stove. Note that the estimated relative risks differ only slightly between the three exposure categories for cardiopulmonary mortality and lung cancer, because those two risk functions are much less sensitive to differences in exposure concentrations.

Table 7. Estimated relative risks (CleanCook stove vs. traditional stove) and percent decrease in risks for using the CleanCook stove (showing best estimate, low, and high exposure categories)

Outcome	**Relative Risk (RR) (traditional vs. CleanCook stove)**			**Percent decrease in risk (CleanCook vs. traditional stove)**		
	low	**best**	**high**	**low**	**best**	**high**
All-cause mortality	1.50	2.26	3.68	33%	56%	73%
Respiratory mortality	2.33	5.41	14.9	57%	82%	93%
Cardiopulmonary mortality	1.54	1.54	1.54	35%	35%	35%
Lung cancer	1.90	1.91	1.91	48%	48%	48%

The estimations shown in Table 7 must be considered preliminary and extremely uncertain as they are based on many assumptions. Personal exposure measurements would improve these estimations. Further, data from on-going studies of indoor air pollution and health around the world should help reveal the exposure-response relationships necessary to more accurately make these estimations of relative risks and percent risk reductions.

Conclusions

The use of the CleanCook stove in place of traditional wood and charcoal stoves in 11 households in the Kebribeyah Refugee Camp resulted in significant reductions in kitchen indoor air pollution concentrations. Forty-eight hour $PM_{2.5}$ levels inside the kitchens were reduced by 94% (from 2.17 to 0.13 mg/m^3) while CO levels dropped by 79% (from 80.7 to 16.7 mg/m^3).

The health implications of these improvements in indoor air quality are difficult to quantify, as this study did not collect any information on the participants' personal exposure or health status. Furthermore, the tools to make such quantifications are not yet robust in the literature. Some preliminary methods to estimate the health benefits of the reduction in kitchen $PM_{2.5}$ concentrations were applied here. These methods, while subject to many assumptions and limitations, led to the following best estimates for the use of the CleanCook stove versus the use of the traditional stove: a 56% decrease in the risk of all-cause mortality, a 82% decrease in the risk of respiratory mortality in children under 5, a 35% lower risk of cardiopulmonary mortality in adults >30 years, and a 48% reduced risk of lung cancer. Although the methodology used to obtain these results relied partly on methods that have been published and promoted by the WHO, it is highly experimental and based on several assumptions that are still widely debated in the scientific community. Therefore, Gaia Association should be prepared to respond to challenges from scientists and health policy makers when making these results public. In CEIHD's view, these results are still valuable, as long as they are presented together with the assumptions upon which they are based, as a preliminary indication that remains to be proven through further research.

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