Pilot Intervention of Improved Cook Stoves in Rural Areas: Assessment of Effects on Fuel Use, Smoke Emission and Health

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ABSTRACT

This study aims to explore the impact of improved cook stoves (ICS) on fuel expenditure (consumption), smoke emission, and health of women (cook) in rural households of Bangladesh. In the follow-up survey (January-March 2010), 1,569 households, constituting of both who received ICS immediately after baseline survey (July-September 2008) and who had refused to use any ICS, were selected for interview using a pre-tested structured questionnaire. The most convincing evidence showed lower fuel expenditure (>60% respondents reported), cooking time (45%), or time spent in collecting fuel for ICS compared to traditional stove. The respondents reported that smoke emission reduced (86.4%) and soot production dropped (89%) due to using ICS. This indicates the importance and potentials of ICS in reducing indoor air pollution and hence less exposure and lower effect on health. We found that 63% of the respondents did not go anywhere for treatment on health problems mainly respiratory illness symptoms such as sore throat and coughs (>90% respondents reported), or eye irritation, difficulty in breathing, night sweats, headache (>75% respondents reported) within 30 days since the interview was done. However, impediments still remained to see clear benefit of ICS by the users such as on technological aspects like design and maintenance of ICS, awareness rising (in terms of importance of ICS) and provision of interim monitoring whether ICS will work well or need supports. ICS intervention was successful in reducing fuel consumption expenditure, time spent in collecting fuel and cooking food, and reducing smoke emission and health hazards. Thus, it is necessary to pay more attention to these impediments to further improve the existing situation.

I. INTRODUCTION

Inefficient cook stoves contribute to deforestation and global climate change, which are costly in terms of time and money required for fuel collection, and pose serious health threats. Recently, it has been estimated that over 3 billion people rely on solid fuels and other biomass for cooking and heating, and most use traditional stoves that are very inefficient in converting wood into heat that cooks food (Burki 2011). The World Health Report identifies emissions generated from burning biomass as responsible for two million deaths every year and for 3.6% of the global burden of diseases (WHO 2010). Many studies have documented that biomass combustion within the household is thought to be the main contributor to indoor air pollution (IAP). So, women who usually cook at households in Bangladesh and the infants and children they care, are particularly affected. The leading killer of children worldwide is acute respiratory infections (ARI) – accounting for 22% of all communicable child deaths in 2004 (WHO 2005). Epidemiological studies identify IAP as a principal culprit, reporting powerful associations between IAP exposure and ARI symptoms (Dey *et al*. 2011, Smith *et al.* 2000, Ezzati and Kammen 2001, Ezzati *et al.* 2004, Pokhrel *et al.* 2005). In rural areas women and girls spend many hours a week in gathering firewood.– As such, they do not have enough time to go to school or other productive work, or for earning money.

Despite the magnitude of this growing health hazards, half of the world's population and over 75% of the South Asians continue to rely on cow-dung, brush and wood as their primary source of energy for cooking and heating (WHO 2002, Ezzati *et al.* 2004, Pokhrel *et al.* 2005). Biomass combustion with traditional stoves is an important contributor to climate change as well. Other than carbon dioxide, the leading contributor to rising global temperatures is black carbon, accounting for 18% of the increase (with CO-carbon monoxide accounting for 40%) (Rosenthal 2011). In Asia and Africa, traditional household cook stoves that burn solid biomass fuels produce the majority of black carbon (Rosenthal 2011); household energy use in Africa alone will produce 6.7 billion tons of carbon by 2050 (Levine and Beltramo 2009).

However, ICSs have not yet reached most of the world's poor (Household Energy Network 2008). Few ICS programmes have included rigorous evaluation of impacts and of barriers to achieve widespread adoption. Rigorous evaluations are crucial to determine whether ICSs actually reduce fuel-use, greenhouse gas emission, and harmful emissions. Recently, a study has identified that health effects of exposure to IAP have yet to become a central focus of research, development aid, and policy making (Burki 2011). Similarly, scientific evaluations are also crucial to understand the cause of slow technology adoption and can provide needed evidence to determine the appropriate response by stove designers, stove distributors, and/or policy-makers (Levine and Beltramo 2010).

ICSs, instead of traditional biomass cook-stoves, can ensure efficiency in the use of traditional fuels (World Energy Council 2005). Moreover, ICS reduces smoke emission and health hazards especially to the cook. In the case of chimney based ICS, the smoke from the stove is also taken out of the kitchen to keep the kitchen clean. Other benefits of ICS include reduced cooking time, less smoke, less blackening of the cooking utensils, saving fuel, portability for portable stoves especially during rainy season, etc. Institute of Fuel Research and Development (IFRD) in Bangladesh developed a number of models of ICSs. Besides, some of the non-governmental organizations (NGO) in Bangladesh are actively involved in disseminating ICS technology among the community members especially in the rural areas. A variety of ICSs have been designed and developed which include both fixed and portable type, metal and clay, single and multiple pot, with and without chimney, with and without grate, etc. At present, more than 100 NGOs in Bangladesh are working locally with different models of ICS (Sarkar *et al.* 2006). Portable cook-stove was preferred during rainy season. Besides, fixed single pot stove without filter plate and fixed double pot stove without chimney were also found in different locations in the country.

A recent study on the promotion of ICS in rural Bangladesh have identified major cooking practices (Arif *et al*. 2011). These include the major types of biomass and non-biomass fuel, types of cook-stoves, knowledge on ICS, major constraints of using ICS, etc. It showed that over 98% of the stoves were traditional and the remaining were of some form of ICS. Solid biomass and agricultural residues were the major fuels used in the study areas. With around 75% of the country's population living in rural areas, consumption of biomass fuel is, therefore, significant (BBS 2008). In another study, we found that women suffered mainly from eye irritation, ARI symptoms, dry cough, sweating at night, etc. because of more exposure to IAP due to use of traditional stoves (Dey *et al*. 2011). Considering the potentiality of ICS to reduce all of these problems, there is a lack of information on the impact of ICS on fuel expenditure (consumption), smoke emission, and health. Therefore, this study is an endeavour to meet the following objectives.

Objectives

The overall objective of the study was to find the impact of ICS on fuel expenditure (consumption), smoke emission, and health of women in rural households of Bangladesh. Specific objectives were to:

- Find out fuel expenditure for ICS compared to traditional stove,
- Explore time spent in collecting fuel and cooking food compared to traditional stove,
- Investigate smoke emission from ICS than traditional stove, and
- Examine self reported health symptoms especially of women due to use of ICSs.

II. MATERIALS AND METHODS

Study area

The two *upazilas* (sub-district), Jamalpur Sadar of Jamalpur district and Hatia of Noakhali district of Bangladesh (Fig. 1), were purposively selected considering the first round intervention as well as cook stove adoption decisions. However, these two areas were selected for the initial intervention based on the findings of the baseline survey where the type of fuel used at household level was considered (Arif *et al*. 2010). In Jamalpur *upazila*, about 94% of the households were using agri-residue as solid fuel for cooking. So, it was selected to represent the area using this particular type of fuel. Hatia *upazila* was next to the area where about 88% of the households were using firewood as fuel. Therefore, Hatia was selected to represent the area where firewood was the most commonly used fuel.

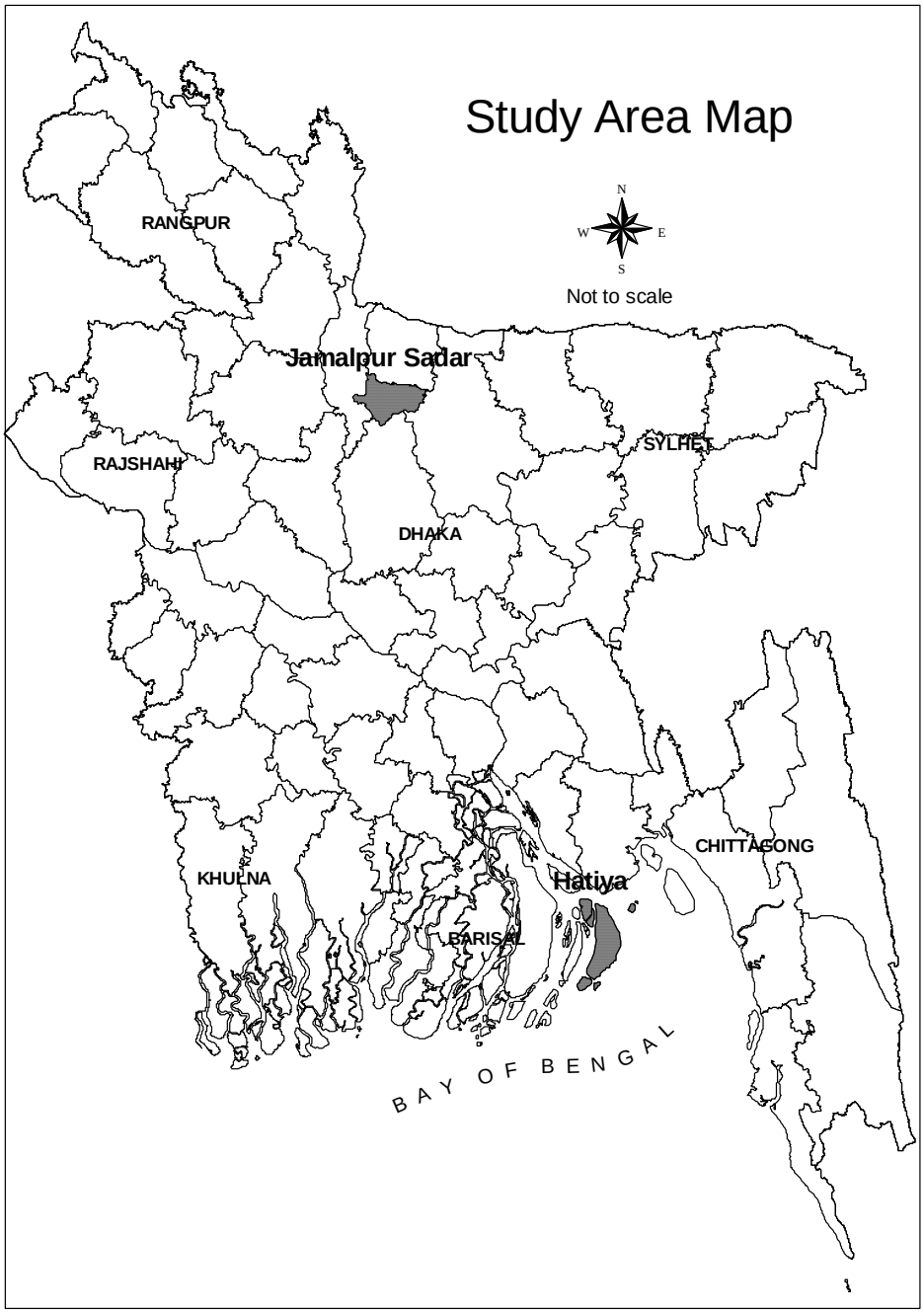
Interventions

In the first round of this study, two rounds of stove tests were done at the field level before selecting ICSs for intervention at household level. After testing a number of stoves two types of ICSs namely 'chimney-based ICS' - a design by German International Corporation (GTZ, recently renamed as GIZ) and 'portable ICS'- a design of Practical Action Bangladesh were considered in this study. The households were divided into intervention groups (A–H) as follows:

Table 1. Intervention conditions of households

Intervention condition	Number of households in Jamalpur	Number of households in Hatia
A: Control: Information plus stove offered at full price	300	300
B: Subsidy: Information plus stove offered at half price	250	250
C: Information plus stove offered at full price and households told whether opinion leaders accepted offer of that stove at full price	250	250
D: Information plus stove offered at half price and households told whether opinion leaders accepted offer of that stove at half price	250	250
E: Men (husband) given the choice of either a portable stove or a chimney stove at free of cost	100	100
F: Women (wife) given the choice of either a portable stove or a chimney stove at free of cost	100	100
G: Men (husband) given the choice of either a portable stove or a chimney stove at subsidized price	100	100
H: Women (wife) given the choice of either a portable stove or a chimney stove at subsidized price	100	100

Figure 1. Study area



Sampling technique

In the follow-up survey (January-March 2010), 1,568 of the 3,080 households were selected based on their decisions to adopt ICS. They were offered different interventions in the baseline. The households were selected from 58 villages of Jamalpur Sadar and Hatia *upazila*, 29 from each *upazila*. A pre-tested questionnaire was used for data collection. All the households who adopted ICS and also all the households who chose not to adopt any ICS but fell in intervention groups E-H, were covered in the follow-up survey. Six hundred households were randomly selected for the follow-up survey from 2,111 households in the A-D groups who refused to adopt ICS in the first round (baseline) (Table 2).

Table 2. Sample selection from households covered in first round

	Jamalpur		Hatia		Total
Decision to adopt ICS in the first round →	Yes	No	Yes	No	
1st Round Survey Group A-D	100	1040	69	1071	2280
1st Round Survey Group E-H	199	200	189	211	799
2nd Round Selected Treatment Group A-D	100	289	69	311	769
2nd Round Selected Treatment Group E-H	199	200	189	211	799

Portable ICS

The selected portable ICS (Photo 1) with grate is made of mud, using the traditional look of portable cook-stove used in rural areas. However, there are some specific interior measurements of fuel chamber, grate and its placement, air flow chamber, stove top diameter, ash collection chamber, height, weight, thickness, etc. to be followed during preparing such stoves. All the traditional biomass fuels cannot be used in this type of stove. Specifically, husk, dry leaves, straw, etc. are not convenient to use as fuel since cast iron grate is used here. Only fire woods like tree branches, bamboo sticks, charcoal, cow-dung, etc. can be used in it conveniently. It has been assumed from the initial stove testing results that the major difference of this stove with the traditional stove may be that it burns the firewood more effectively and reduces the quantity of firewood required for cooking. Time for cooking may be same or less than the traditional stove. It produces almost same amount of smoke like the traditional stove. It can be used inside the house during rainy season. Price of such stove in the market varies from Tk. 800 to Tk. 1,000 (rate of January 2010).

Chimney-based ICS

The selected chimney-based ICS (Photo 2) with grate is made of mud like the traditional one and fixed with the ground/earth. However, there are some specific measurements to be followed in making this ICS in terms of fuel chamber, grate, air flow chamber, stove top diameter, ash collection chamber, height, weight, etc. This ICS can be of I or L shaped and consist of single or double burner. Besides cast iron grates, ten feet long and six inches diameter concrete chimney, smoke cap, etc. are used. These stoves can be installed 50% under the ground (in terms of height) or

100% above the ground. In most of the cases, mostly clay materials are used inside the stove to channel smoke to the roof top smoke cap through chimney. Not all of the traditional biomass fuels can be used in this stove. Like portable ICS only firewood can be used as fuel. The main difference of this stove with the traditional stove is that it burns the firewood more effectively thus reduce the quantity of firewood required for cooking. Time for cooking can be same or less than the traditional stove. It produces less amount of smoke compared to the traditional stove. Price of such stove in the market varies from Tk. 1,500 to Tk. 2,500 depending on the availability of the clay soil and use of brick or cement coat (rate of January 2010).

Data collection and analysis

Informed consent was obtained from the respondents. Seventy field enumerators were recruited and trained. They were divided into 35 teams - 18 for Hatia and 17 for Jamalpur Sadar *upazila*. Two enumerators were responsible to supervise the quality of filed work at Hatia and Jamalpur. The filled-in questionnaires were edited and coded for computer entry under the close supervision. Twenty percent of the questionnaires were re-checked. The analysis was performed using SPSS version 16.0.

Photo 1. Portable ICS

Photo 2. Chimney-based ICS

III. RESULTS

Socioeconomic profile of the respondents

Most of the participants were 20–59 years old and married. About half of them were literate. The main occupation among males was agriculture followed by business. The females mostly reported household work as their occupation (Table 3).

Table 3. Basic socio-demographic profile of respondents

Indicators	Jamalpur Sadar		Hatia	
	Male (%)	Female (%)	Male (%)	Female (%)
Age group in years				
Adolescent (10 – 19)	-	2.9	-	2.1
Adults (20 – 59 years)	83.4	92.7	81.2	93.9
Older (60+)	16.6	4.4	18.8	4.0
Married	99.5	99.5	99.9	99.6
Literate	45.5	48.1	59.5	54.1
Occupation				
Agriculture	44.4		41.0	
Business	21.2	0.3	23.1	0.1
Day labour	19.1	0.1	18.4	0.3
Household work		98.4		97.5
Others	15.3	1.5	17.5	2.1
Earning member	98.2	28.0	97.6	9.2
Average family size	5.76 (±2.196)		7.34 (±2.928)	
N	1,539	1,539	1,540	1,539

Use of stove and condition of kitchen

Table 4 shows different types of stoves used in the study areas. Data revealed that 94% of the households mainly used traditional stoves for their major cooking. Besides, 5.6% of the households used chimney-based ICS. Sixty percent of the respondents reported of using more than one stove. Of them, 76.5% used traditional stoves, 13% chimney-based, and 9.6% portable ICS for secondary cooking. Traditional stove was being used at a higher rate in Hatia than Jamalpur Sadar for secondary cooking.

Table 4. Stove use

Stove types	% Households		Total
	Jamalpur Sadar	Hatia	
Primary use			
Chimney based ICS	5.8	5.4	5.6
Portable ICS	0.3	0.0	0.1
Traditional stove	93.9	94.0	93.9
Chimney based traditional stove	0.0	0.7	0.3
N	742	744	1,486
Secondary use			
Chimney based ICS	12.8	13.1	13.0
Portable ICS	17.9	1.8	9.6
Traditional stove	69.4	83.2	76.5
Chimney based traditional stove	0.0	2.0	1.0
N	445	446	892

Reasons for using multiple stoves

Around 38% of the respondents reported that the main reasons for using multiple stoves were seasonal variations - indoor stove for rainy season and outdoor for dry season (Table 5).Other reasons include use of different types of fuel (35.8%), less time required for cooking (18.9%), portability of stove (2.5%) (for portable ICS), less soot production (2.1%), etc.

Table 5. Reasons for using multiple stoves to cook

Stove types	% Households		Total
	Jamalpur Sadar	Hatia	
Take less time to cook	15.6	22.1	18.9
One of them is portable	3.9	1.1	2.5
Use of different fuels in different stoves	20.0	50.8	35.8
One stove costs much to cook	0.7	1.3	1.0
Indoor stove for rainy season, outdoor stove for dry season	52.2	24.3	37.8
Less soot production	3.9	0.4	2.1
Did not use stove	3.5	0.0	1.7
Chimney is easy to clean	0.2	0.0	0.1
N	431	457	888

Sources of ICS, condition of working/not of ICS, and cooking with ICS

Around 35% of the respondents reported that they received ICS from BRAC. Of them, 53.8% reported that their stoves were active since installation; the rate was higher for Jamalpur Sadar (64.3%) than Hatia (42%) (Table 6). Besides, over 33% respondents reported that they cooked some of the meals using ICS while 33% used it for cooking all meals, and 24% cooked most of the meals. However, rest of the users (8.5%) did not cook with the stove.

Table 6. Source of ICS, status of working/not of ICS and cooking with ICS

	% Households		Total
Source, working/not condition/cooking with ICS	Jamalpur Sadar	Hatia	
ICS from BRAC			
Yes	37.3	32.5	34.9
No	62.7	67.5	65.1
ICS still working			
Yes	64.3	41.7	53.8
No	35.7	58.3	46.2
Proportions of the meals cooking with the ICS?			
All meals	36.8	28.9	33.1
Most of the meals	24.2	24.0	24.1
Some of the meals	30.0	38.4	33.9
Never	9.0	7.9	8.5
N	742	744	1,486

Influence of ICS to change traditional stove

Over 93% of the respondents reported that they did not change their old stoves (Table 7). Those who changed their old stove were mainly due to the influence of the ICS provided by BRAC which was higher in Jamalpur than Hatia.

Table 7. Influence of ICS to change traditional stove

Influence of ICS to change traditional stove	% Households		Total
	Jamalpur Sadar	Hatia	
Made changes to the old traditional stove			
Yes	6.9	6.9	6.9
No	93.1	93.2	93.1
N	742	744	1,486
Any influence of the ICS provided by BRAC to change traditional stove			
Yes	78.4	64.7	71.6
No	21.6	35.3	28.4
N	51	51	102

Placement of stoves

In the follow-up survey it was observed that most of the stoves were placed inside the kitchen which was an enclosed compound near the main residence (63.0%). Some were in an open space nearby the main house (19.6%) or completely in the open space (15.3%), and a few (2.1%) were inside the main residence (Table 8) (not in the kitchen).

Table 8. Placement of stove inside or outside kitchen

Placement of stove	% of respondents		Percent
	Jamalpur	Hatia	
Enclosed	61.0	65.0	63.0
Inside the main building	2.4	1.8	2.1
Open	15.0	15.6	15.3
Averagely open	20.2	19.0	19.6
N	742	744	1,486

Satisfaction level of stove users

The level of satisfaction regarding the taste of cooked food by traditional stove (85.7%) was higher compared to chimney-based ICS (76.9%), portable ICS (75%), and chimney-based traditional stove (66.7%) (Table 9). Besides, level of satisfaction on the ease of firing the stove (75.4%) and availability of fuel (71.8%) was higher for traditional stove. In addition, satisfaction level regarding cooking time was nearly similar. The respondents reported that their satisfaction level on the scope of doing other works while cooking was higher for chimney-based ICS users compared to other stove users. Also sustainability of the chimney-based ICS was higher compared to the other stoves.

Knowledge on indoor air pollution (IAP)

Less than 5% of the respondents thought that there was no IAP inside their house, while 27.67% thought that there was significant amount of IAP taking place. About 67% thought that little to moderate IAP took place in their living compound. Besides, they also thought that cooking was indeed a source of pollution. One-fifth of the respondents who thought no IAP occurred inside their houses opined cooking as a source of pollution (which could perhaps explain why they thought no pollution occurs in their houses). Most of the respondents recognized cooking as a source of IAP where 89.4% attributed this pollution to fuel, while 20.2% attributed to stove. Regardless of everything else, 87.3% of all the respondents realized that pollution was harmful to health.

Overall experience of ICS compared to traditional stoves

Table 10 shows the respondents' experience about ICS performance regarding 'time saved' and 'use of saved time'. ICS saved time compared to traditional stove according to over 57% respondents. The saved time could be used mainly for cleaning or sweeping rooms/surrounding (40.9%), taking care of children (21.5%) and domestic animals (14%), sewing *kantha* (13.6%), collection of fuel (8.6%), etc.

Smoke emission

The share of the respondent's opinion in favour of using ICS was highest for reduced smoke emission (86.4%) and chance of food getting burnt (70.2%) (Table 11). Besides, soot production dropped to 89.1% and time required to clean kitchen reduced to 82.5% due to use of ICS.

Table 9. Perceived satisfaction level of stove (primary stove) users

Satisfaction/dissatisfaction	Primary stove type				Total
	Chimney based ICS	Portable ICS	Traditional stove	Chimney based traditional stove	
Satisfaction level on the taste of cooked food					
Dissatisfied	1.1	0.0	0.7	0.0	0.7
Neither satisfied nor dissatisfied	4.4	25.0	11.1	0.0	10.7
Satisfied	76.9	75.0	85.7	66.7	85.1
Very satisfied	17.6	0.0	2.5	33.3	3.4
N	91	4	1,388	3	1,486
Satisfaction level on firing the stove					
Dissatisfied	8.8	25.0	2.9	0.0	3.3
Neither satisfied nor dissatisfied	12.1	0.0	19.0	0.0	18.5
Satisfied	65.9	75.0	75.4	66.7	74.8
Very satisfied	13.2	0.0	2.7	33.3	3.4
N	91	4	1,388	3	1,486
Satisfaction level on availability of fuel					
Dissatisfied	7.7	0.0	3.4	0.0	3.7
Neither satisfied nor dissatisfied	17.6	50.0	16.9	0.0	17.0
Satisfied	65.9	50.0	71.8	100.0	71.4
Very satisfied	8.8	0.0	7.9	0.0	7.9
N	91	4	1,388	3	1,486
Satisfaction level on cooking time required					
Dissatisfied	5.5	0.0	7.8	0.0	7.6
Neither satisfied nor dissatisfied	11.0	0.0	28.8	33.3	27.7
Satisfied	57.1	75.0	57.4	33.3	57.4
Very satisfied	26.4	25.0	6.0	33.3	7.3
N	91	4	1,388	3	1,486
Satisfaction level on scope of doing other works while cooking					
Dissatisfied	2.2	0.0	13.2	0.0	12.5
Neither satisfied nor dissatisfied	17.6	0.0	25.8	0.0	25.2
Satisfied	59.3	100.0	54.0	100.0	54.5
Very satisfied	20.9	0.0	7.1	0.0	7.9
n	91	4	1,388	3	1,486
Satisfaction level on the sustainability of the stove					
Dissatisfied	1.1	0.0	5.4	0.0	5.2
Neither satisfied nor dissatisfied	13.2	50.0	25.4	0.0	24.6
Satisfied	70.3	25.0	54.6	66.7	55.5
Very satisfied	15.4	25.0	14.6	33.3	14.7
n	91	4	1,388	3	1,486

Table 10. Perceived performance of ICS as compared to traditional stoves

Performance	% Households		Total
	Jamalpur Sadar	Hatia	
Can save time using ICS			
Yes	68.3	45.7	57.4
No	26.2	51.3	38.3
Can't say	5.6	3.0	4.3
n	252	234	486
Mean time saving (in minutes)	33.4 (±1.0)	30.0 (±1.0)	32.1 (±0.7)
Utilization of saved time			
Taking care of children	20.4	23.4	21.5
Sewing *katha*	19.8	3.7	13.6
Taking care of domestic animals	16.3	10.3	14.0
Washing clothes/dishes	8.1	17.8	11.8
Cleaning or sweeping rooms/surroundings	29.1	59.8	40.9
Bathing	1.7	9.4	4.7
Collecting fuel	13.4	0.9	8.6
Teaching children	2.3	0.0	1.4
Handicraft	0.6	1.9	1.1
Talking over phone	0.0	0.9	0.4
N	172	107	279
Mean time required to be used to with new ICS (days)	4.5 (±0.3)	4.2 (±0.3)	4.3 (±0.2)

Table 11. Perceived smoke emission from ICS compared to traditional stove

Perceived issues of comparisons	% Households		
	Jamalpur Sadar	Hatia	Total
Amount of smoke			
Less	92.1	80.8	86.6
Similar	4.4	13.7	8.9
Much	3.5	5.6	4.5
Amount of burning cooked food			
Less	65.1	75.7	70.2
Similar	28.6	19.7	24.3
Much	3.2	2.5	2.9
Don't know	3.2	2.1	2.7
Soot production			
Less	92.1	85.9	89.1
Similar	6.0	11.1	8.4
Much	1.2	2.1	1.7
Don't know	0.8	0.9	0.8
Time requires to clean kitchen			
Less	87.3	77.3	82.5
Similar	9.1	16.7	12.8
Much	1.6	4.3	2.9
Don't know	2.0	1.7	1.9
N	252	234	486

Time required in cooking food using ICS compared to traditional stove

The respondents reported (42-45%) that less time required for cooking food using ICS compared to traditional stove both in rainy and dry seasons (Table 12). However, around one-third of them (33-36%) experienced that it required almost similar time compared to traditional stove. Besides, 7-15% reported of more time required for cooking food using ICS.

Table 12. Perceived time required in cooking food using ICS as compared to traditional stove

Perceived issues of comparison	% Households		
	Jamalpur Sadar	Hatia	Total
Time requires to cook food in rainy season			
Less	48.0	41.9	45.1
Similar	35.3	30.8	33.1
More	9.5	22.7	15.8
Don't know	7.1	4.7	6.0
Time requires to cook food in dry season			
Less	39.7	43.6	41.6
Similar	36.9	34.2	35.6
More	4.4	9.8	7.0
Don't know	19.1	12.4	15.8
N	252	234	486

Time required in collecting fuel for ICS

Table 13 shows time required in collecting fuel for ICS than traditional stove both for Jamalpur sadar and Hatia *upazila*. Over 33% of the respondents reported that less time required in fuel collection for ICS. Besides, 36.2% opined similar time requirement and more than 27% mentioned much time requirement in doing so for ICS.

Table 13. Perceived time required collecting fuel compared to traditional stove

Perceived issues of comparison	% HH		
	Jamalpur Sadar	Hatia	Total
Time required in collecting fuel than traditional stove			
Less	29.0	38.9	33.8
Similar	33.3	39.3	36.2
Much	34.5	20.1	27.6
Very much	1.6	0.0	0.8
Don't know	1.6	1.7	1.7
N	252	234	486

Reported time saving due to use of ICS

The ICS users could save 30-40 minutes per day (Fig. 2). Besides, the respondents required 2-7 days to became used to with ICS (Fig. 3).

Figure 2. Time saved per day using new ICS (minutes)

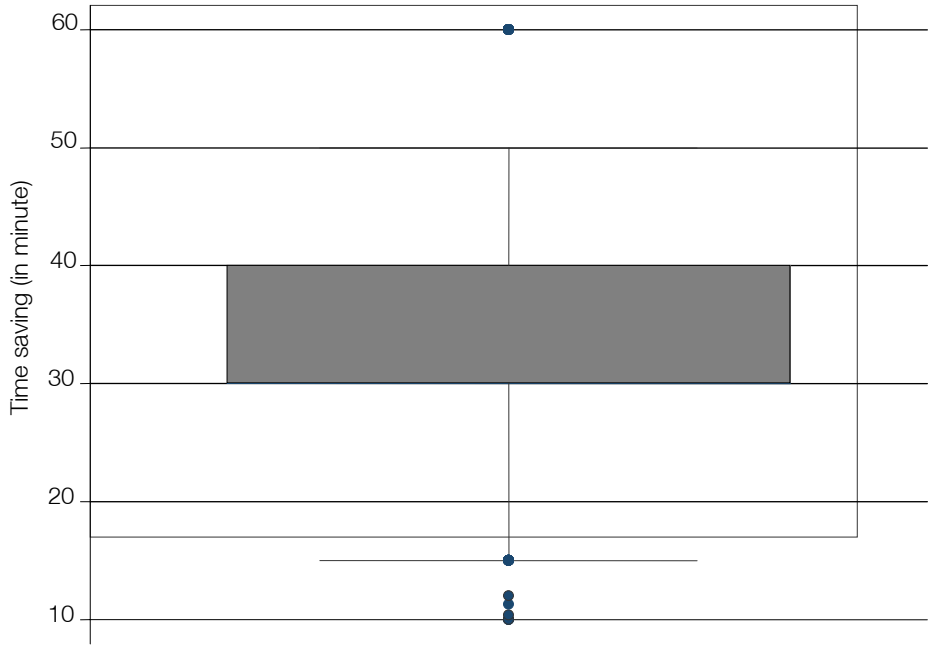
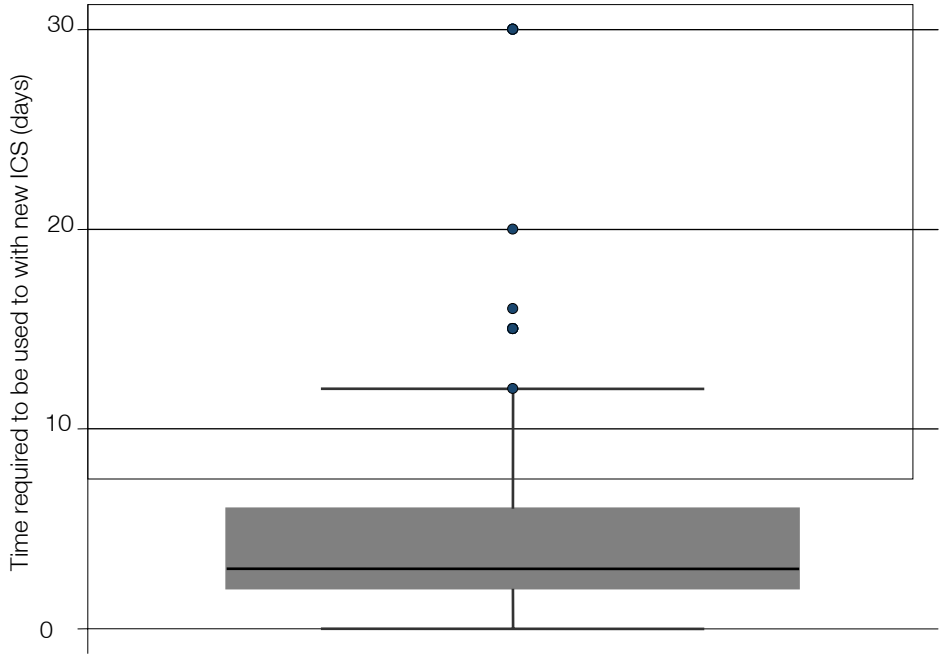


Figure 3. Time required to be used to with new ICS (days)



Perceived fuel expenditure for ICS and traditional stove

The respondents reported that by using ICS they could save over 60% in fuel expenditure compared to that for traditional stove (Table 14). The mean fuel cost reduction was found to be Tk. 90.7 (±10.6). But, 35.2% of the respondents did not find any difference in fuel cost between traditional stove and ICS.

Table 14. Perceived fuel expenditure for ICS and traditional stove

Perceived on fuel expenditure	% Households		
	Jamalpur Sadar	Hatia	Total
Cost of fuel for ICS than traditional stove			
Less	66.7	53.4	60.3
Similar	29.0	41.9	35.2
Much	3.2	2.6	2.9
Very much	0.4	0.0	0.2
Don't know	0.8	2.1	1.4
Mean cost decrease (Taka)	88.9 (±9.9)	93.3 (±23.3)	90.7 (±10.6)
N	252	234	486

Health condition of the household members in the last 30 days

Most of the respondents reported that they did not have any health problems, such as illness (62.1%), respiratory illness symptoms such as sore throat (94%) and dry cough and cough with phlegm (above 90%), headache (86.4%), running nose (74%), painful or swollen joints, eye irritation (93.6%), difficulty in breathing (97.6%), night sweats (96.5%), and fever (83.9%) (Table 15).

Table 15. Health condition of the household members in the last 30 days

Res-ponses	Study areas	Health conditions										
		Ill-ness	Sore throat	Head-ache	Run-ning nose	Vomi-ting	Painful/ swollen joints	Eye irrita-tion	Difficulty in brea-thing	Night sweats	Dry cough	Fever
Yes	Jamalpur	31.0	5.01	17.02	32.7	3.8	5.7	8.0	2.9	4.2	10.6	14.9
	Hatia	42.6	6.51	10.2	20.3	2.8	4.1	4.7	1.5	2.4	7.5	16.4
	Total	37.6	5.85	13.3	25.7	3.3	4.8	6.1	2.1	3.2	8.8	15.8
No	Jamalpur	68.5	94.6	82.7	66.9	95.7	93.9	91.6	96.7	95.4	89.0	84.7
	Hatia	57.2	93.3	89.6	79.5	97.0	95.7	95.1	98.4	97.4	92.3	83.4
	Total	62.1	93.9	86.4	74.0	96.4	94.9	93.6	97.6	96.5	90.9	83.9

Health condition of the respondents and children absenteeism

Table 16 shows that 63% of all the respondents did not go anywhere for treatment while it was higher at Jamalpur Sadar (71.3%). Sixteen percent of the households visited only village doctor while 5.7% visited qualified doctor. More than 52% of the respondents reported that their children sometimes sit beside stove while they were cooking.

Table 16. Perceived health condition and status of children absenteeism

Basic information	% Households		
	Jamalpur Sadar	Hatia	Total
Went for availing health care facilities			
Thana health complex	2.8	8.6	5.7
District hospital	5.1	2.3	3.7
MBBS doctor/clinic	5.4	6.1	5.7
Pharmacy	7.4	4.0	5.7
Kabiraj/hekimi	0.5	0.0	0.3
Village doctor	7.1	25.1	16.2
Did not go anywhere	71.3	53.6	62.5
Upazila health centre	0.3	0.1	0.2
Home doctor	0.0	0.4	0.2
Satellite/community clinic	0.1	0.0	0.1
Children's absenteeism in school in last 30 days			
0 day	31.1	24.1	27.6
1 day	42.5	49.7	46.1
2 days	15.2	13.8	14.5
3 days	8.1	9.3	8.7
4 days	3.1	3.1	3.1
Mean	1.1 (±0.0)	1.2 (±0.0)	1.1 (±0.0)
Children's absenteeism in school due to illness in last 30 days			
0 day	31.1	24.1	27.6
1 day	61.7	62.4	62.1
2 days	4.0	9.7	6.9
3 days	2.3	3.0	2.6
4 days	0.8	0.9	0.9
Mean	0.8 (±0.0)	0.9 (±0.0)	0.9 (±0.0)
How often you/your children sit beside stove while not cooking			
Never	41.1	48.4	44.8
Sometimes	54.5	50.7	52.6
Often	1.9	0.9	1.4
All the time	2.4	0.0	1.2
Can't say	0.1	0.0	0.1
N	742	744	1486

Women's empowerment

Ten percent of the women were the members of women's cooperative societies and most of them (84.5%) attended meetings organized by any organization. Nearly half of the women attended one to two meetings, around one-fifth three meetings, and above one-fourth more than five meetings in a month (Table 17-Appendix),

The respondents reported a number of reasons for changing old stove. Some of these were difficulty in maintenance and more time required for cooking. Besides,

difficulty of using in rainy season, higher soot production and broken of old stove were some other reasons for using ICS. In view of decision for buying ICS, women were found to be the main decision-makers (74%). Besides, women and their husbands jointly took decision to buy ICS in 13.1% cases. However, regarding perception on ICS about two-third of the husbands opined that the stove would mainly reduce fuel cost. Nearly half of the female respondents reported that they discussed with their husbands for formulating any decision for the family. However, about 88% of the female respondents reported that they had to ask their husbands before buying anything.

IV. DISCUSSION

Realizing the potentials of ICS in reducing IAP and hence better environment for better health, this study assessed fuel expenditure, smoke emission and self-reported health attributes for use of ICS in rural Bangladesh. Popularity of the ICS was also investigated in terms of all these factors among women and their husbands.

ICS impacts

Stove use

The use of ICS was improved in the follow-up survey, and the choice was mostly chimney-based ICS. Besides, relatively less use of traditional stoves was found compared to baseline. Households who received ICS from BRAC in Jamalpur Sadar were at a higher rate (64.3%) in using the stove since installation compared to Hatia (42%). It resembles that ICS is much popular in Jamalpur Sadar than Hatia. Besides, one-third of the respondents cooked all meals and one-fourth cooked most of the meals in ICS which indicates increasing rate of ICS adaptation. However, about 93% were not interested to change their traditional stove. It may be because of adaptation with it from long time although the traditional stove has low efficiency, emits smoke with high pollutant, requires more time for cooking, needs higher fuel cost, and makes kitchen environment dirty (Dasgupta *et al.* 2004). Studies identified that some households tend to modify stoves during maintenance leading to reduction in efficacy and increasing IAP. Also, according to some respondents the current design of chimney would make it difficult to maintain and fit in all types of houses. Chimneys with rough inner surfaces have potentials to result accumulated soot and clogging which might require a great deal of cleaning works. Besides, there were some poor families among the respondents who were not capable enough in paying for minor maintenances cost of their ICS, such as replacement of grate, chimney, etc.

Fuel expenditure, time spent in collecting fuel, and cooking food

The respondents were asked whether fuel expenditure, time spent in collecting fuel and cooking food in ICS increased or decreased compared to the traditional stove. The most convincing evidence showed less fuel expenditure (>60% respondent reported) and lower time required in cooking food in ICS both in dry and rainy seasons and nearly half of the respondents reported it. Besides, more than one-thirds of respondents reported that less time was spent in collecting fuel for ICS. These findings are similar to that reported elsewhere (Sarker *et al*. 2006, Household Energy Network 2010). Saving time in collecting fuel and cooking result in more free time and less fatigue, both of which have a direct impact on the time available for childcare and improving the quality of kitchen environment.

Smoke emission

During discussion with the people regarding ICS better answer was found in case of reduced smoke emission (86.4%), chance of food not getting burnt (70.2%), dropped soot production (89.1%), and less time required to clean kitchen (82.5%). These findings are consistent with that of other research (Dasgupta *et al*. 2004, Dherani *et al*. 2008, Ezzati and Kammen 2001, Sarker *et al*. 2006).

Considering placement of stove, improved status was observed during the follow-up survey where most of the stoves (63.0%) were placed inside an enclosed space near the main building. This indicates that people became more aware on IAP and also household members became more aware on the corrective measures of IAP. The location of the stoves gives an idea about how much the pollution from the stoves can affect other living areas, and thus expose other family members to smoke other than the cook herself/himself. As it appears from these statistics, most of the stoves were placed at least at some distance from the main living area and hence other members of the family would not be exposed to the smoke as much as they would have been if the stoves were inside the main building.

Self-reported health

Realizing the potentials of ICS in reducing IAP and hence less exposure and lower impact on health, the study found that nearly two-thirds of the respondents did not go anywhere for treatment within the last 30 days. The findings are consistent with the results of some recent studies (Burki 2011, Ezzati and Kammen 2001, UNCCD 2010). People did not need to go to the doctors for any treatment because they did not face any health problems, mainly respiratory illness symptoms such as sore throat and cough, eye irritation, difficulty in breathing, night sweats (>90%), and headache, running nose, fever (>75%). All these health problems mainly occur due to smoke.

Awareness

Findings suggest that households were aware of IAP but not so much so of ICS use. However, demand for ICS may not be properly understood unless how well the participants understand IAP and its consequences. In addition, study identified that the users, especially women were not fully understand the technological aspects and proper maintenance of ICS which might be the result of not using of new technology. Moreover, many users were not aware of the health impacts of exposure to IAP, which is particularly important if they are to be motivated to use ICS exclusively in order to reduce exposure to IAP. Majority of the research identified that although women are highly affected due to IAP and major users of ICS but they were less included than male participants in the awareness raising or technology use and maintenance-related training programmes conducted by different stakeholders (Dey *et al*. 2011, Winrock International 2008). Many research have documented that awareness raising materials should be targeted to the key audience, in a format that is easily understandable and accessible. Locally appropriate awareness raising tools should be explored as these are often more salient to the target audience.

Issues of not using ICS after adoption

Technological aspects

Some users claimed that the temperature/heat in the ICS during cooking was low and required more time to cook. This is because of the design of ICS which allowed passing out some heat and fire through the large channel and caused heat deficiency. It was not possible to displace fixed ICS from open place especially during rainy season and from closed/dark environment to open place during winter season. In such case the stove had to be reconstructed with the help of experts, which the users could not do. Besides, smaller cap on the chimney allowed rainwater to enter and thus damages stove. In addition, ICS needed extra care to keep it fit for cooking as it used to become cracked frequently due to heat and getting wet. In some cases, it was not possible to cook for large number of family members at a time, because the design of ICS did not allow using larger pot for cooking with it. Although ICS with different diameters (6 inches to 12 inches) of cooking hole were available in the market, but for this particular intervention stove with only 8 inches diameter was used (Arif *et al*. 2011). On the other hand, small family stopped using it because more time and more fuel were used for single cooking. Small-sized biomass fuel pieces were comfortable to fire in portable ICS. Frequently removal of ash from the chimney-based ICS during cooking was troublesome and some users felt boring and stopped using it. Some of the household members opined that the depth of grate placement was undersized, so ashes started to pile immediately after starting cooking and caused insufficient combustion which leaded to more time to cook. Also, grate of ICS was stolen in some cases. These users were reluctant to purchase the grate again and hence they stopped using it since without grate the ICS did not perform perfectly.

Fuel options

Some of the users complained that they could not use all kinds of fuel according to their choice in the ICS which they could use in traditional stoves. However, they had to buy some special fuel for ICS. They had opportunity to get agricultural residues, leaves, and branches of trees at free of cost for cooking. Since these fuels were not suitable for ICS they stopped using it.

Availability of raw materials and time constraint

In some cases, soil quality was not up to the required level (especially in Haita) and also there were lack of other instruments and materials which led the users reluctant to reconstruct the damaged chimney-based ICS. They also opined that more time was needed to construct chimney-based ICS. In such cases they stopped using improved stove because of damage and they could not manage time to reconstruct it.

Maintenance

In some cases the users did not pay proper attention for maintenance of ICS. Regular monitoring and follow-up by service provider was not maintained properly. Besides, raw materials for constructing ICS were not available in local market.

Social culture

There were some users who felt uncomfortable to use ICS as they were not habituated. This is not always possible to change fuel (in terms of quality, quantity, size and category) or adopt new shape of stove instead of so long, often over generations, old cooking practice. Cooking is such a sensitive issue on which many of the households did not want to take any risk.

V. CONCLUSION

The increasing acceptance of the ICS shows positive impacts on fuel expenditure, smoke emission and self-reported health conditions. Findings suggest that households were usually aware of IAP but not so much in spite of using ICS. Besides, most of the respondents realized IAP as harmful to health**.** The result of ICS use was found to be better than traditional stoves in less fuel expenditure, less time spent in fuel collection and cooking, reduced smoke emission, and lower effect on health. However, some technological aspects, such as design and maintenance of ICS and awareness rising related to the importance of ICS, and provision of interim monitoring could be materialize to see the clear benefit of ICS.

VI. RECOMMENDATIONS

With a view to increase the use and demand of ICS, following recommendations can be made:

Technological aspects

ICS should be designed with provision of using major types of biomass fuels used in the locality. The depth inside the stove should be enlarged, so that the removing of ash and/or charcoal from inner part of the stove would not require frequently. Besides, design should consider different size of pots used by local people. ICS users must be discouraged to change the dimensions and designs on their own.

Awareness raising

Awareness raising activities can be conducted on the efficacy and IAP reduction potential of ICS. Awareness raising materials should target the key audience in easily understandable and accessible format. Locally appropriate awareness raising tools should be explored as these are often more salient to the target audience. ICS users, who are satisfied, can be incorporated in such campaign to promote ICS locally. There should be a provision of subsidy especially for the poorest so that they will continue using ICS.

Monitoring

Effective monitoring by the organization promoted ICS may ensure its sustainable use.

Involving women

Women as the primary users of ICS can be included in the awareness raising or technology use or maintenance-related training programmes. Besides, different studies have noted that there was strong potential to engage women as technicians and entrepreneurs. Since IAP is an issue which inherently involves women and household level cooking needs, it is very important to design a programme where women have equal voice as users, technicians and entrepreneurs.

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APPENDIX

Table 1. Women's empowerment

Women's cooperatives and self help groups	% Households		
	Jamalpur	Hatia	Total
Member of any women's cooperative or self help group			
Yes	13.8	6.2	10.0
No	86.3	93.8	90.0
n	742	744	1486
Attend meetings			
Yes	84.3	84.8	84.5
No	15.7	15.2	15.5
n	102	46	148
Numbers of meeting attended last month			
One meeting	31.4	30.8	31.2
Two meetings	17.4	10.3	15.2
Three to four meetings	19.8	18.0	19.2
More than five	24.4	33.3	27.2
Can't say	7.0	7.7	7.2
n	86	39	125
Average stay at each meeting			
30 minutes or less	23.8	25.0	24.1
30-60 minutes	52.5	25.0	44.0
1 hour or more	23.8	50.0	31.9
n	80	36	116
Stove related decision making			
Reason for changing old stove			
Tough maintenance	23.4	45.7	36.5
Much time required for cooking	43.4	22.3	30.9
Bad taste of the cooked food	3.7	0.0	1.5
Unavailability of fuel	5.4	13.3	10.1
Cooking was not easy	12.9	0.3	6.5
Can't use during rain	2.3	1.2	1.6
Much soot production	3.9	0.9	2.1
Using fuel was not easy	6.2	0.3	2.7
Room replacement	1.7	0.1	0.8
Stove was broken	0.0	17.6	10.4
n	482	692	1174
Decision maker for purchasing/building current stove			
Wife	64.3	80.6	73.9
Husband	8.5	9.5	9.1
Wife and husband jointly	24.3	5.4	13.1
Other family members	2.9	4.5	3.8
n	482	692	1174

(Appendix Table 1 continued.....)

(.....Continued appendix Table 1)

Husband's perception about the new stove			
Taste of the cooked food would be good	8.9	9.4	9.2
Fuel cost would be less	72.4	48.0	58.0
Child's health would be better	14.9	0.9	6.6
Cough problem would be reduced	9.8	3.6	6.1
Less smoke would be produced	1.5	0.1	0.7
Doesn't have husband/can't say	6.0	39.9	26.0
n	482	692	1174
Relationship with husband			
Never	5.4	13.3	9.4
Sometimes	24.7	35.1	29.9
Often	19.5	9.7	14.6
Always	49.2	40.9	45.0
Don't know	0.5	0.3	0.4
Widow/separated/divorced	0.7	0.8	0.7
n	742	744	1486
Need permission from your husband to buy something for self			
Yes	80.6	95.4	88.0
No	17.9	4.5	11.2
Can't say	1.5	0.1	0.8
n	733	736	1469