Household Energy Program For Reduction of Exposure to Indoor Air Pollutants

Project Report No. 2

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A. Background

Right Track is a Kolkata,India based NGO working in both rural and urban areas to improve the living conditions of the poorer sections of the society by providing education. They are presently working in urban slum areas of Kolkata. Their objective is to provide improvement in quality of air, drinking water, sanitation using better technologies in an integrated project.

A survey conducted in the study area revealed that the children and women in these urban communities were having severe health problems due to poor indoor air quality, unsafe drinking water and poor sanitation system.

Poor indoor air required intervention to bring changes in cook stove and fuel used for the cook stove and better ventilation. It was understood that low cost and highly efficient cook stove would have a strong role in bringing about an improvement in the indoor air quality for these communities. One of the strong recommendations for the study was to involve local youth for production of low cost and highly efficient cook stove with the help of locally available materials. The logic behind the recommendation was that it would bring down the cost of the improved cook stove which are usually more expensive than the traditional stoves.

Right Track subcontracted Appropriate Rural Technology Institute (ARTI),Pune to undertake the 'Household Energy Program For Reduction of Exposure to Indoor Air Pollutants' in the slum areas of Kolkata,India. Dr Karabi Dutta was the project coordinator for the project.

Initially five slums of Kolkata, Howrah and 24 Parganas (South), West Bengal were identified for intervention. Most of these settlements are situated on the banks of river Ganga. Community youths both male and female who lived in these slums were inducted into the program as field workers. ARTI began the project by arranging an an awareness camp for the community youth and Right

Track staff to explain the benefits of improved indoor air and impact of improved cooking stoves in improving the indoor air quality. Later the volunteers were provided a training in manufacturing improved stoves

B.1. Project Details
Sub Recipient: Appropriate Rural Technology Institute (ARTI)
Contracting Agency: Right Track,Kolkata
Funding Agency: GOAL,India
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Single Pot mud stove	**Bucket stove**	**Double pot mud stove**

Fixed mud stove

2. Report

Indoor Air Quality (IAQ) Monitoring

Particulate matter (PM) and carbon monoxide (CO) were measured in the households selected for the study. Monitoring was done for 24 hours in these houses which use traditional stoves.

PM was measured using the UCB. The UCB was set to record PM concentration every minute in its memory. It is sensitive to particles of aerodynamic diameter less than approximately 2.5 microns called fine PM or

$PM_{2.5,}$ which is the size range thought to be most important for health. The monitors were produced and individually calibrated in the Indoor Air Pollution Laboratory at UC Berkeley prior to their use. CO was measured with a commercial CO logger, which also recorded concentration every minute. They were purchased new and calibrated at the Indoor Air Pollution Lab at UC Berkeley using standard CO gas..

Household Selection.

Five urban slums of Kolkata were selected for the study based on the criteria of stove type and fuel use pattern. The areas selected for the study are as follows:

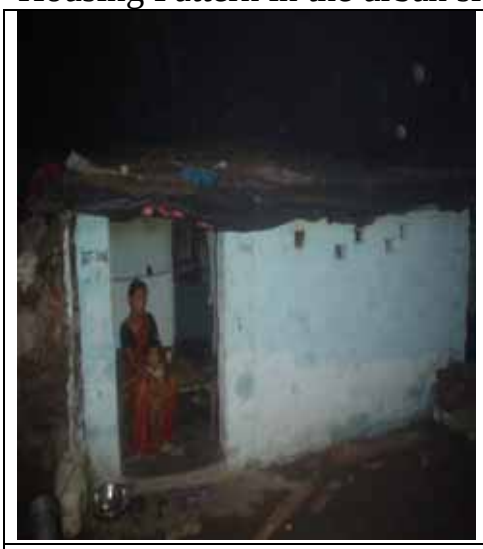
Table1: Stove types and fuel preferably used in each slum area

Sr no.	**Area**	**Stove Type**	**Fuel used (usually)**
1	Khalbari	Single pot fixed mud stove	Bark and sawdust
2	Shalimar	Single pot fixed mud stove and bucket stove	Coal briquette small wood pieces, bagasse
3	Panchur	Single pot fixed mud stove	Wood, sticks ,dry leaves
4	Coalberth	Bucket stove	Coal briquette
5	Bichalighat	Bucket stove	Coal briquette

A Screening Questionnaire (Appendix 2) was used by field staff of Right Track upon their first visit to approximately 50-60 households in these areas to ensure that the household was suitable for and amenable to the study. The criteria for selection were as follows:

- Housing structure and design
- Family size
- Presence of young children below the age of 5 years
- Income
- Permanent or migrant residents in that area
- Cook stove used
- Fuel used
- Presence of other types of cooking stoves and fuels
- Presence of LPG stove
- Willingness to participate in the study

Housing Pattern in the urban slums – OUTSIDE VIEW

		
No windows	Plastic roof	Kitchen in the enclosure outside the main room

Housing Pattern in the urban slums – INSIDE VIEW

		
One roomed house	Kitchen below the bed	Cooking in the bucket stove

Methodology

- The traditional stoves was monitored for testing. After completion of data collection, a data cleaning and database compilation was done. Analysis of the data was done following the compilation.

- Although personal pollution exposures are the best indicator of health impact, they are substantially more difficult to measure in household settings and introduce additional variability and ethical considerations. It was decided to focus on stationary IAQ measurements in the kitchen, which is the most sensitive area for measuring changes in IAQ due to stove pollution. While the percentage reductions in indoor levels may not be equivalent to reductions in personal exposures (due to time spent coming in and out of the kitchen), the metric provides a measure of the effectiveness of the ICS and biogas in reduction the high levels of smoke in the kitchen from open fires, and can be deployed for a longer time period in the home. Personal exposure samples can usually only be deployed for 24 hours as they impose considerable burden on participants, causing higher drop out rates. Indoor samples can sample for longer which reduces some of the variability associated with daily variation in cooking activities.

- This is also consistent with many dozens of other studies undertaken around the world, mostly for research purposes, that have used indoor measurements due to the complexity and high participant impact of collecting personal exposure samples.

- Although there are many pollutants in biomass smoke that probably play a role in the wide range of health effects that have been measured or suspected, it was decided to focus on the two most measured pollutants small particles and carbon monoxide. Each is created by somewhat different processes during combustion and has different mechanisms of action in producing health effects. Thus, they probably cover a good part of the spectrum of toxicity of the smoke, but certainly not all. Reductions in both, however, can probably be viewed as a good indication that most other pollutants have been reduced as well.

- To reduce variation between measurements in the same house, a perennial problem with household studies, a 48-h rather than the more commonly used 24-h measurement period is preferred but due to the lack of time the 24-h measurement period was done.

- At each household, a UCB and HOBO were placed next to each other on the wall of the kitchen for 24 hours, using defined criteria. At the end of each sampling session, a Post-Monitoring Questionnaire (Appendix 1) was administered to the main cook of the household. The questionnaire documented cooking and other activities that may have affected the kitchen IAQ during the monitoring period.

Results

There are considerable differences in the stoves and fuel use in each slum area. In addition to the fuel difference, there are, of course, considerable differences in the traditional foods cooked in different regions of India and the stove designs reflect these differences. This part of the study is part of the larger study wherein interventions will be sought to improve the indoor air qualities presently existing in these households. The present indoor air quality levels have been recorded under the study. As is known the primary source of pollution in these urban slum houses is the cooking fuel and the stove. So interventions will be sought to improve the fuel quality and stove design keeping in mind the cooking habits and vessels used by the cooks in this region.

Table 2: Average PM and CO values of traditional stoves in different slum areas of Kolkata and comparison with WHO Guidelines

KOLKATA	PM (mg/m3)	WHO interim target-1	WHO Air Quality Guideline	CO (mg/m3)	CO (mg/m3	CO (mg/m3)	CO (mg/m3)	WHO Air Quality Guideline
Area	24 hr ave	(24-hr mean)[1]	(24-hr ave)[1]	24 hr ave	cooking period ave	Max	Min	(8-hr ave)[2]
Coalberth	1.553	0.075 mg/m^3	0.025 mg/m^3	7.885847	27.31302	126.2125	0.22904	10 mg/m^3
Bichalighat	1.014			6.385635	10.38238	94.93708	0.22904	
Khalbari	0.259			1.68917	9.986144	21.32935	0.22904	
Panchur	0.386			2.416372	11.05118	61.34035	0.22904	
Shalimar	0.638			7.031528	17.73915	71.05966	0.22904	

Although CO and PM were measured in the same location, it would be expected that the reductions as a result would not exactly agree, since they are produced

by different combustion processes, and behave somewhat differently (gas versus particles).

It is conceivable that that stove usage patterns are the dominant factors in variability and should be addressed through more targeted screening questionnaires in addition to clearly distinguishable differences in housing design and family size.

The IAQ summaries here refer to household in which the stoves were compared were in use, i.e., traditional stoves in the "Before" phase. They also do not indicate the presence of other combustion sources in the household environment, such as kerosene stoves or LPG stove which can influence results.

From the table above it can be seen that Panchur and Khalbari show the least CO and PM values. This is probably because in Panchur people cook only 1 meal a day and they use mostly wood sticks and dry leaf as fuel. In Khalbari the fuel used is bark of trees and they usually cook in a 3 side enclosed area which is an extension of the main house. Thus the ventilation is reasonably good.

Comparison of IAQ Results with WHO Guidelines

The World Health Organization (WHO) sets air pollution guidelines to offer guidance in reducing health impacts 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 which 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 project households are compared to the World Health Organization's AQG and interim target-1 (WHO, 2005)

It can be seen that particle concentrations and CO levels are far above WHO guidelines, even the most liberal Interim Target-1.

Recommendations

- The project achieved its midterm objective in providing an estimate of the IAQ status in the slum households. In this the NGOs should be commended.

- Drop out of households between sampling rounds plagued the groups requiring care in choosing sample sizes Such losses occurred because households refused to continue or had moved away, or otherwise became unavailable and in some cases the household numbers given at the beginning of the study do not match thus complicating and delaying the study. In these cases houses should be assigned numbers by printing them on the entrance door or wall. While collecting household information from the participant and community in depth questioning should be done to find out if they are permanent settlers or a floating member of the community who are staying there for a short period on rent.

- Multiple fuel and stove use in some areas complicated the collection and interpretation of changes in fuel use and air pollution. In such areas, future studies may have to do more careful stratification of households to obtain the statistical power to make judgments.

Finally after the midterm evaluation of the project and the status of the Indoor air quality (IAQ) in the study areas it is recommended that to bring about an improvement in the indoor air quality of the urban slum households it is necessary to intervene with new improved stove models and fuels by :

Introducing existing improved stove models available to suit the cooking habits of the people of this region: The stove performance test result and field survey show that the improved Grihalaxmi stove which is a cement single pot stove with 2 grates is ideally suited for the fuel used by the people in Khalbari. The householders use tree bark which can be burned quite efficiently in these stoves.(Project report1). Chimney stoves although ideal for improving IAQ, cannot be used in any of these 5 study areas because the roofing materials are flammable and even a small splinter or spark may lead to a major fire. Also the height of the households are not more than 5-5.5 feet .So if chimneys are installed the chimney portion above the roof will be not more than 6-6.5 feet thus putting it almost at the noselevel of men and women. It will also create a smoke blanket over the houses at a relatively low level which is dangerous and very unhealthy. In my previous communication I had recommended Grihalaxmi for Panchur too but after the recent visit to Panchur the following observations were made:

Remarks after a visit to Panchur on 14th February,2007 :

It must be said at the onset that during my preliminary visit to Kolkata in April,2006, to survey the study areas and meet the project Facilitators, Panchur was the only place I did not have an opportunity to visit. The information on Panchur was collected on the basis of the questionnaires and discussion with project facilitators. During my visit to Kolkata, in February, 2007, I had the opportunity to visit Panchur. The house to house visits in Panchur revealed the following:

1. Most of the households cook in traditional 1 pot cookstoves which are fixed–the design of which is unique for that village. This chulha design was not found in the other 4 slums.Other households use portable bucket stove and coke as fuel.
2. The cooking area is the verandah which is semi-enclosed with cane mattings serving as wall probably to protect the stove from wind which will interfere with stove performance.It also has a temporary roof. Thus there is no indoor smoke. Smoke from outside too cannot enter the households because the brick and mortar houses have been constructed in such a way that there are no windows or doors near the area where cooking is performed. So the living quarters are not exposed to smoke.
3. The cooking fuel is coal or coke briquettes, wood is used as a fire starting material only.
4. The cost of coke or coal is Rs 3.00 per kg whereas wood costs Rs 4.30 per kg.

So the previous interpretations on Panchur were wrong. The present interpretations are:

- The CO and PM concentrations are low because they cook in the veranda and the monitors too were kept in the verandah to measure preintervention monitoring.
- Low emissions of PM or CO were recorded since the wind was blowing away the pollutants.
- wood is not the preferred fuel,coal is the preferred fuel in 95% of the households.

So under the circumstances the Grihalaxmi stove which was recommended for Panchur will be a a bad decision since the Grihalaxmi is a wood burning stove and . Also we would be asking them to spend more money on fuel (wood) if we insisted on introducing the Grihalaxmi.

Designing new stoves: In all the other remaining areas (Shalimar, Coalberth, Bichalighat and Panchur), the main fuel is coal or coal briquettes.They use the bucket stove but that too is highly polluting since

- the briquette quality is bad
- the stoves are not scientifically constructed thus making them inefficient.

To overcome these obstacles, The ARTI team has developed and designed a new coal cum wood burning stove which burns efficiently with minimum emissions. This stove will be piloted in Panchur in the next phase of intervention in April. Since the stove is cheap and uses combination fuel, it is expected that it will be well accepted by the study population. Also other existing improved stove models can also be piloted to check the suitability.

Improving the fuel: The pre intervention study has shown that the study population use very low grade fuel of low calorific value (Project Report1). Sometimes the fuel may be good but it is not used properly, for example saw dust is burned as a loose powder. This leads to greater consumption of fuel and more emissions. It is recommended that new cheap fuel alternatives which have higher calorific value be introduced by modifying the existing fuels available to them.

Sawdust and coal powder can be easily made into high quality fuel if they are made into briquettes with appropriate binders. ARTI has the expertise in making briquettes from various fuel alternatives and this can be introduced as a new enterprise for the local youth.

Modification in kitchen architecture: As a final recommendation it is suggested that emphasis be given to proper well ventilated kitchen structure wherever applicable. But in the slum households this is very difficult to implement but suggestions can always be made. Another important point to be kept in mind is if a household cooks food in a semi-enclosed or open area, they should be encouraged to continue to do so since it reduces exposure to pollutants and under no circumstances should they be encouraged to install stoves inside their homes.

In the following intervention studies the following exercises are important and should be conducted by the NGO staff.

a. the degree to which the ICSs are actually put to use
b. the extent to which traditional stoves remain in use (with or without the ICS)
c. the durability of the ICS in real kitchens
d. householder suggestions for improvements to the design or construction of the stove to keep maintain good IAQ, which may

only be revealed after extended use (perhaps best revealed by focus group discussions, kitchen performance tests etc.)