Biofuels, Pollution and Health Linkages: A Survey of Rural Tamil Nadu
Author(s): Jyoti Parikh and Vijay Laxmi
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Biofuels, Pollution and Health Linkages

A Survey of Rural Tamil Nadu

In the context of the current concern about indoor air pollution due to the use of biofuels, a comprehensive survey to capture ground realities becomes essential. This paper reports the results of a survey which looks at the fuel supply and consumption patterns, people's exposure to these fuels and its health impact.

JYOTI PARIKH, VIJAY LAXMI

Rural population obtains 90 per cent of cooking energy from biofuels such as fuel wood, crop residues and animal dung. These biofuels result in very high levels of indoor air pollutants. This issue has been neglected in energy, environment, health and economic policy for decades and is now poised for major policy and programme initiatives. Only a comprehensive analysis could channelise energy and environment policy and health initiatives in proper direction. This requires an understanding not only of the socio-economic aspects, but of other factors also, is led below.

- What is the extent and magnitude of biofuels in the rural areas and how difficult it is to get them?
- Why do clean fuels have limited presence in the consumption basket despite the fact that many other consumer durables as well as consumables have already entered? Is there a willingness to pay for clean fuels?
- What interventions are acceptable to the rural people among clean fuels, improved stoves or ventilation?
- Which groups suffer most from the health risks?
- What are the levels of pollution exposures due to biofuels to chief cooks and others who are present. What are the determinants such as fuel, stoves, house type, kitchen type, ventilation and so on?
- What is the linkage between exposure and health? Do they produce symptoms that medical doctor can verify? Do they affect lung capacity over time?
- What is the role played by health centres? Do they find more cases of air and water pollution?
- What are the environmental priorities of people themselves? Do they give higher weight to water pollution and sanitation due to their immediate effect on their health in the short term?

These are some of the questions addressed by a comprehensive survey initiated by Indira Gandhi Institute of Development Research (IGIDR) for 4 states, viz, Himachal Pradesh, Rajasthan, Tamil Nadu and Uttar Pradesh. In this paper we look first at how the fuel supply is obtained, fuel consumption patterns, and whether people have the desire to change it; second, how the exposure to pollution from these fuels vary with attributes such as kitchen locations, cooking practices, type of housing etc and thirdly, health impact on women due to prolonged exposure and the response of medical professionals. This paper reports on the survey conducted in the rural areas of Tamil Nadu covering 5,028 households from 30 villages and 4 districts. The multilayered study involved surveys within the survey to get to the bottom of this issue. Along with socio-economic variables, views on intervention that can lead to success, people's perception about these issues, we also included measurement of body mass index and lung capacity, experts to measure pollution and medical doctors to check health status.

Interventions are now being planned by several agencies such as World Bank, United Nations Development Programme, World Health Organisation and many other aid agencies. At this juncture it is essential to get a comprehensive picture to channelise these interventions in the right direction.

I Survey Design

Surveys conducted earlier have been limited to some specific objective. Thus, in some surveys we have pollution measurements but not enough information about socio-economic characteristics or in some cases disease prevalence but no measurements of level of pollution. Moreover, most of them were limited, rarely covering more than 400 households [Smith 1996; Saxena and Dayal 1997]. This makes it difficult to understand a lot of uncertainties in linking pollution with symptoms and physical conditions of human beings. Our aim was to carry out a comprehensive survey with a large sample so that many doubts and uncertainties can be removed. Thus, a team of experts visited 10 per cent of the sample households to measure the air pollution along with doctors to check the health profile of all individuals present. Socio-economic and other household details, as well as individuals' self-reported information was collected through appropriately designed questionnaire.

Villages were selected using multistage sampling design. At the first stage, stratification of state was done on the basis of its socio-cultural regions (SCRs). Tamil Nadu (TN) was divided into four SCRs. At the second stage, selection of one district per SCR was done based on the population of the districts and the district with median population in the SCR was selected. At stage three, allocation of households to be surveyed from each district was based on the universe distribution of rural households. Then stratification of each selected district was done by village population size. The villages were divided into four strata on the basis of population. In stratum 1 villages with population less than 1,000 were included, stratum two had villages with population 1,000-3,000, whereas in stratum 3 villages with population between 3,000-5,000 were included. The 4th stratum was for villages having population more than 5,000. Stratum four was excluded from the sample. The selection of the villages from each stratum was done using population proportion sampling.

Selection of households within the selected village was performed using systematic random sampling. The number of households from each district and in each stratum is given in Table 1.

The survey was conducted at three levels, viz, household level survey including individual responses for health status, village level survey and survey of nearby health care facility (health centre) which villagers availed (for example, primary health centres, public health centres, government hospitals, etc). Village level and health centre (HC) surveys were performed for the purpose of validation of data acquired at household and individual level, and also to get an overall picture of the area. This also helped in economising the number of questions. For example, in a village level survey one ascertains fuel sources, schools, health facilities and doctors' availability along with distance from the road, any air polluting industry, etc. HC survey indicates what types of diseases are reported in the area, what type of facilities are available, what are the high and low seasons for respiratory diseases etc. At the household level a multi-pronged approach was used to collect different types of information. The methods used were the following:

- Face to face interview with chief cook
- Symptom inquiry and health assessment with measurement of weight, height and lung capacity with peak flow meter.
- Diagnostic with medical professionals
- Measurement of pollution levels and individual exposure with state-of-the-art, equipment

The data at household level were collected to have a complete picture of socio-economic conditions, fuel consumption pattern, cooking behaviour, villagers' exposures to selected indoor air pollutants generated during the combustion of biofuels, and health profile of the individuals, so as to link pollution with health and other confounding variables. Village level information was collected from the head of the village panchayat, whereas HC level information was collected from administrative officer or chief resident doctor. (See the Figure 1a and Figure 1b for over all picture of the survey). The total sample size information is as follows:

Total no of village level interviews: 25 interviews (based on availability of head of panchayat)

Total no of HC level interviews: 9 interviews.

Total no of households covered: 5,028 household interviews

Total no of individual health record: 22,251 household members

Total no of lung function records: 12,000 individuals

The methodology for collecting the information from household is explained below for each of these components.

Data were collected through face to face interview of the chief cook of the house. The information collected was age, literacy and income status, asset structure, willingness to pay for different improvements to reduce kitchen smoke, time activity pattern of the members of the household, environmental concerns of the respondent.

Information was collected on different type of fuels and the quantity used for cooking, source and distance from where find if, the fuel was collected the price paid for purchasing different type of fuels. Information regarding availability of kerosene and willingness to switch to clean fuels was also collected.

Information in this category was collected from the chief cook of the house. The queries regarded the type of house and kitchen, location of kitchen, meals cooked in a day, quantity of fuel used, type of stove, availability of clean fuel etc.

The data were collected for exposure to different pollutants, viz, respirable suspended particulates (The particles with aerodynamic diameters <10 fg or PM_{10}), NO_2, CO and SO_2 in 500 households. These households were the sub-sample of 5,028 households selected randomly from 4 districts. Both the indoor air and outdoor air was monitored.

For PM_{10}, personal samplers were placed inside and outside the kitchen during various time windows. Exposure for the cook while cooking was always assessed with personal sampler attached to the cook. Since the availability of samplers did not permit attaching a sampler to each and every member of the household, area measurements using the same samplers were taken as surrogates for exposure for the others. Exposures at all times other than cooking were determined through area measurements.

For Monitoring Gases: Carbon monoxide, sulphur dioxide and nitrogen dioxide levels were determined only while cooking was going on, in the same households that were monitored for PM_{10}. (For details of instruments used please see the appendix 1.)

A high volume respirable dust sampler was placed on the roof of the tallest available building within the village and run for a duration that varied between 2-10 hours, depending on the availability of power. The outdoor air monitoring for gases was performed only during cooking hours and at a different location as during the rest of time they were below the limit of detection.

To understand the health profile of the individuals the task was divided between the three groups,

1 Trained surveyors to handle the questionnaire based on MRC (Medical Research Council) questionnaire on respiratory symptoms, 1986.

2 Physicians to confirm the disease

3 Trained surveyors to measure peak expiratory flow readings.

The surveyors were trained by a physician to collect health data through MRC questionnaire on respiratory diseases. Therefore, for 5,028 individuals direct responses were available, whereas, for absent members proxy data were collected from the respondent. Thus a proxy response on health status were collected for 17,223 individuals. They were also trained to collect height weight and peak expiratory flow readings (PEF) of all the individuals available in 5028 households during interview. For the PEF the subjects were required to blow thrice in the peak flow meter and best of the three reading was recorded. The recording of PEF is an objective test. PEF was not administered for the children below 6 years of age. This is the biggest strength of this study as the PEF data that measure lung capacity were collected from 12,000 individuals.

The senior physician, who was responsible for reviewing the individual case sheets before making a final assessment, supervised a group of junior doctors. These

Table 1: Distribution of Households in Districts in Different Strata

District	<1K	1-3K	3-5K	Total	Per Cent
Chengalpet	330	851	516	1697	34
Coimbatore	78	376	467	921	18
Tirunelveli	154	326	230	710	14
Trichy	80	863	757	1700	34
Total	642	2416	1970	5028	
Per cent distribution	13	48	39		100

doctors performed physical examination of all the symptomatic cases found through questionnaire for identifying the disease. Besides this the doctors also visited all the indoor air quality monitoring (IAQ) households and examined all the available individuals whether they were symptomatic or not.

Results of the survey are presented in the following manner. In SectionII village characteristics including infrastructure facilities and health care facilities are presented. Section III deals with socio-economic conditions prevailing in the area. Different characteristics of fuel use are discussed in Section IV including fuel use pattern, time and effort involved in fuel wood collection, access to use of clean fuel, price willing to pay for clean fuel and reasons for not using the clean fuel. Housing conditions and cooking practices are discussed in Sections V and VI respectively. Exposure to indoor air pollution and over all health status is presented in Sections VII and VIII. Linkages between biofuels use, different cooking practices and type of house with health are established in Section IX. Section X deals with main environmental concerns of the rural women.

Figure 1a: Sampling Procedure

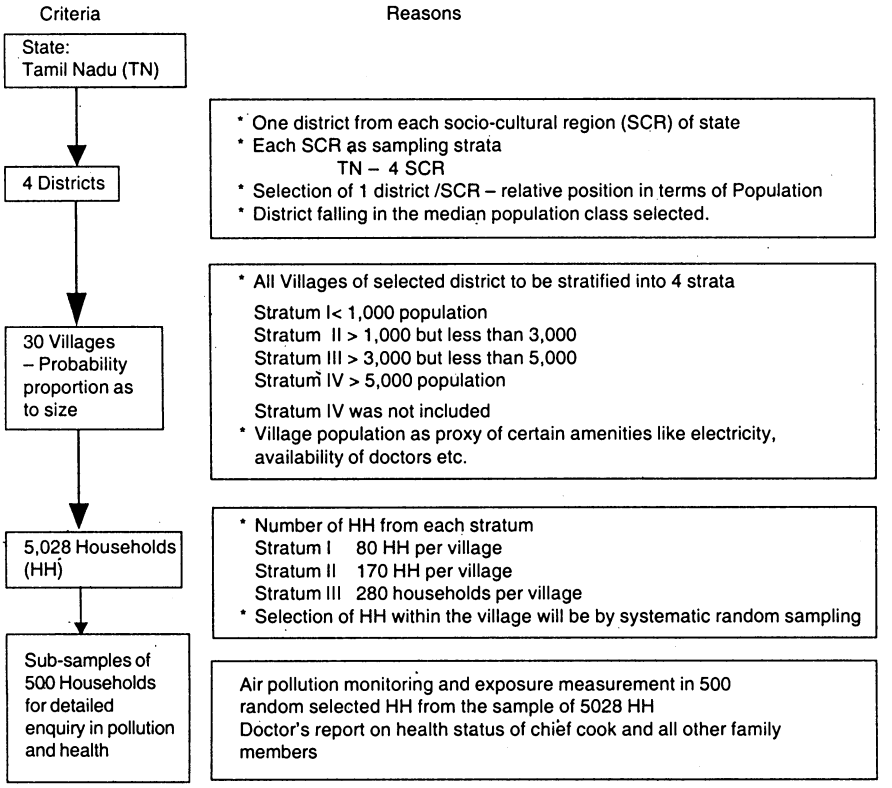
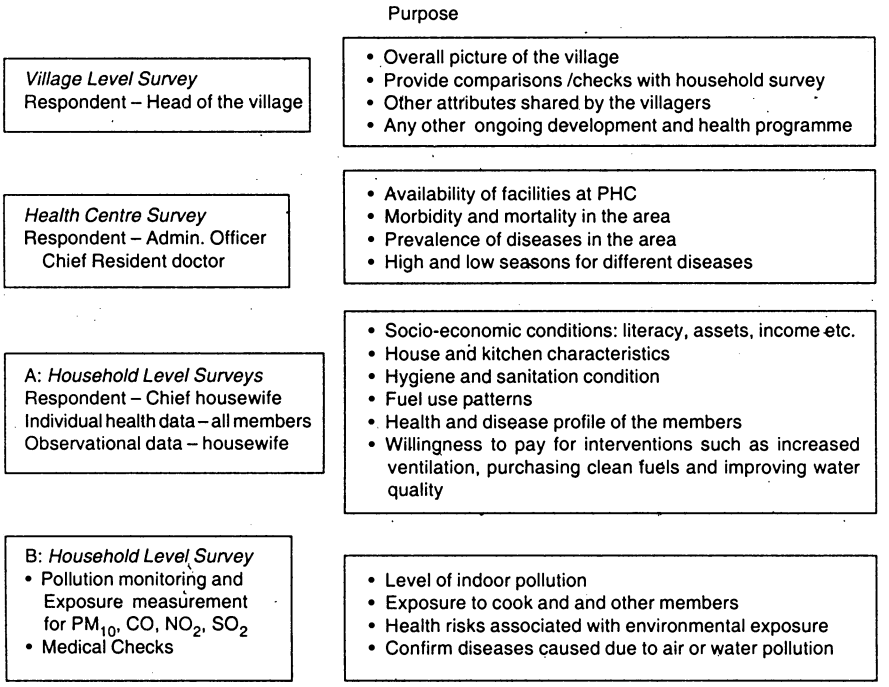


Figure 1b: Four Levels of the IGIDR Survey



II
Village Characteristics

Village characteristics include demographic details, infrastructure facilities, heath care facilities.

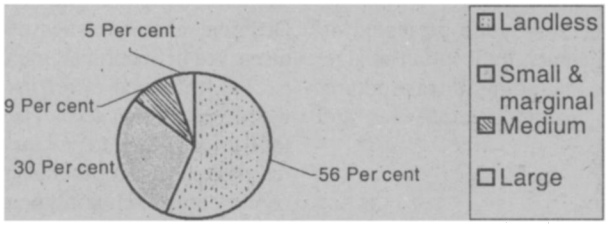
The four districts, namely, Chengalpattu MGR, Coimbatore, Tirunelveli K and Tiruchirapalli were selected from four socio-cultural regions, covering all the three corners and central region of the state (Table 2). These four districts together comprise 24.4 per cent of the state's rural population. Universe characteristics of the districts are as follow:

There is a predominance of the medium size villages (1-3K population) in the districts covered. Therefore, 48 per cent of households belong to this stratum in our sample.

The survey reveals that in the area female population is higher than male population. Population distribution is such that there are 1,050 females per 1,000 males. Sexwise age distribution is indicated in Table 3. Male literacy is higher than the female, as 68 per cent of males are literate whereas, in case of females this percentage is just 51 per cent.

The survey shows that most of the villages have some road network and mode of transportation. In the selected villages 64 per cent of the villages have pucca road within half a kilometre distance and another 20 per cent villages have pucca road within one kilometre. The remaining 16 per cent villages have pucca road at a distance beyond 2 kilometre. Only 24 per cent of the sample villages have the railway station within a distance of 5 kilometres. A large majority of villages (76 per cent) however have the railway stations beyond 5-kilometre distance.

Figure 1: Land Holding



Distance from the nearest town incidentally followed the pattern of distance from railway station. Only 24 per cent of the sample villages have a town within a distance of 5 kilometres. Since the majority of the sample village is close to pucca roads, the main mode of transport is bus. In addition, there are other modes of transport like tractor, bullock cart and bicycle.

Almost all the villages have a primary school except one village, and 36 per cent of villages have secondary schools. In the area none of the village have any vocational training centre or any degree college.

Almost all villages (96 per cent) have dispensaries/clinics some of which are part of health centres or hospitals. Moreover, most of the villages also have primary health centres/government hospitals/hospitals by NGOs/private hospitals. Average distance to the nearest hospital ranges between 2.5 to 3.2 km. Approximately 76 per cent of the sample villages are also covered through mobile health units. Pathological laboratory facilities are also available to 76 per cent of the villages within a distance of about 2 km. Presence of any polluting industry also affects the health of the local people. Village level survey shows that about 35 per cent of the sample villages have industry nearby. Most of these industries are located within a radius of 5 km from the village. All these industries are non-polluting type (neither air or water) except for one brick industry found near village Veerapandi in Chengulpet district.

III
Socio-economic Conditions

Majority of villagers (56 per cent) are landless and about 30 per cent of the villagers are either small or marginal farmers (see Figure 1) having land area less then or equal to 5 acres. The income structure shows that 56 per cent of the households have income less than Rs 10,000 per annum. 27 per cent of the households have income between Rs 10,000 to Rs 50,000 per annum, and only 17 per cent of the households have income greater than Rs 50,000. As against the estimated proportion of low-income households of 56 per cent by panchayat office, sample proportion of households derived from our household survey is 45 per cent. Thus, at least 45 per cent of households belong to low income category with annual income less than Rs 10,000 (less than Rs 850 per month).

The survey shows that approximately in 80 per cent of the villages (Table 4), people share open water sources which are not used for drinking. In 40 per cent of the villages, grazing and pasture lands are available as CPRs.

The different types of durables owned by the household reflect the purchasing power of a household. Statements about income are often found to be unreliable in surveys. A more reliable indicator of income would be ownership of consumer durables. The survey reveals that most of the households (65 per cent) own a wall clock and 50 per cent own a wristwatch (Figure 2). Fan and radio, is owned by 45 per cent and 46 per cent households respectively. Forty-three per cent households have a kerosene pressure stove. At least these 43 per cent households who already have kerosene pressure stove can be expected to switch to the next cleaner fuel on energy ladder, i e, kerosene if made available in sufficient quantities.

IV
Different Characteristics of Fuel Use

Characteristics of fuel use include issues such as what is the major fuel used for cooking, time and effort involved in getting that particular fuel and availability of other type of fuels in the area.

In rural Tamil Nadu biofuels are still the main source of cooking fuel for about 96 per cent households. Use of dung cake for cooking is not very common in the area. Kerosene is mostly used for lighting purpose, which is explained below. In Tamil Nadu, almost 100 per cent villages have been electrified, except for Trichy district. The electrification of the villages in the study area is shown in Figure 3. The panchayat heads reported that 65 per cent of rural households have been electrified in the areas. But according to our households survey only 26 per cent of the households are electrified. These households are mostly pucca houses.

The results of the study show that fuel wood is the main source of cooking fuel. Average consumption of fuel wood is 2.5 kg per household per day in the area. Only 8 per cent of the households were using clean fuels, like kerosene or liquid petroleum gas for cooking purposes, whereas 61 per cent were using fuel combination, i e, biomass and clean fuel (Figure 4). Where combination of clean fuels and biofuels are used, kerosene is mainly used

Table 3: Age Composition by Sex

Base: All individuals	Male 10851 (Per Cent)	Female 11400 (Per Cent)
< 5 years	11	10
6 – 10 years	10	10
11 – 15 years	10	10
16 – 20 years	10	12
21 – 40 years	35	38
41 – 55 years	15	14
> 55 years	9	6

Table 4: Sharing of CPRs*
Number of villages 25

Resources Shared	Total (Per Cent)
Open water sources - not used for drinking	80
Open water sources - used for drinking	24
Grazing land	40
Forest, of which	
– Village forest	16
– Government forest	12
– Forest department's forest	8

*As enquired from head of each village.

Table 2: Sample Coverage

Characteristics (Per Cent)	Tamil Nadu Total	4 District Total	Study Covered
Population (Mn)	36.78	8.97(24.4)	0.02(0.2)
No of villages	16780	4327(25.8)	30(0.7)
No of households ('000)	8430	2120(25.1)	5(0.2)
Average no of HHs per village	503	489	168

Figure 2: Durables Owned (Per Cent Households)

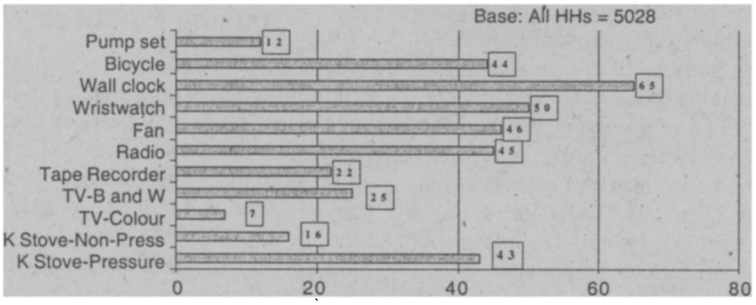


Figure 3: District Villages Electrified

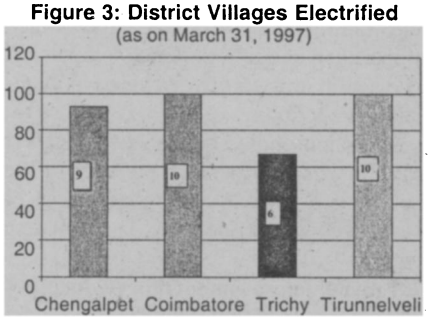


Figure 4: Fuel Consumption Pattern

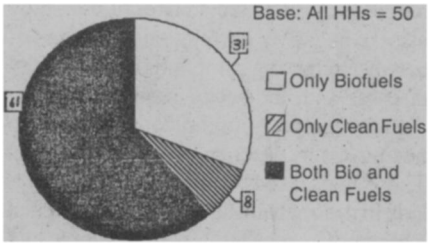
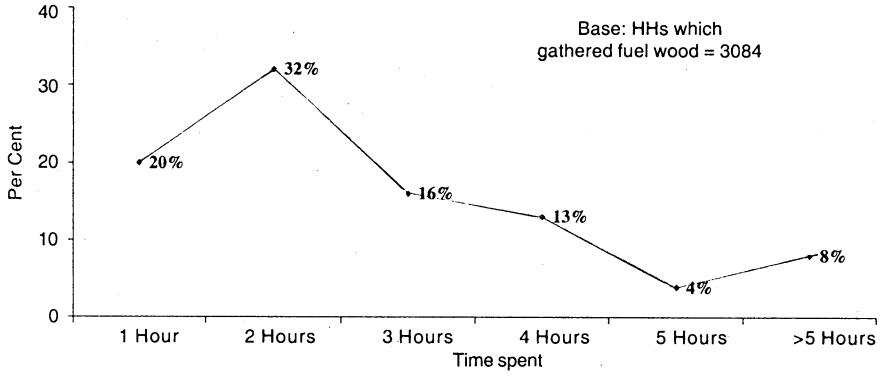


Figure 5: Average Time Spent in Collection of Fuel-wood
(Person hours/household/trip)



for lighting and cooking snacks or very small meals. Main meals in these households are cooked using fuelwood. This is obvious from the very small amount of kerosene consumed per household, i e, on an average 2.1 litres per household per month, and the fact that only 26 per cent households are connected with electricity. When the lighting fuel is subtracted (3 to 5 litres, on average per household) than only 18 per cent households remain who are using kerosene for cooking (Table 5).

Seventy-three per cent of the households generally gather fuel wood from village and government forests and very few households purchase fuelwood. These fuel wood collecting households mostly send one person. In some cases, however, 2 persons are engaged for collection of fuel wood. On an average 8 trips per household are made in a month to collect wood. In most of the villages the distance travelled to collect wood is less than 1 km (Table 6). Average distance to collect the fuel wood is about 1.5 km. Thus, in a month a distance of 12 km is travelled for gathering the required quantity of fuel wood.

Average time spent on collection of wood is around 2.5 hours per trip per person (Figure 5). Therefore, approximately 20 hours per month per household are spent on fuel wood collection. Except for person hours involved in collection of fuel wood there is no other expense involved towards fuel wood collection.

Availability of clean fuel is not sufficient in the study area. The kerosene supplied through public distribution system (PDS) is mostly restricted to a quota of 3 litres per household, whereas, two out of 25 villages do not receive kerosene through PDS and one village reported to have an irregular supply of kerosene. In the survey area 92 per cent of villages have infrastructure for kerosene. At least 43 per cent of households have facilities to use it but only 18 per cent of households are actually using kerosene for cooking.

The use of clean fuel is higher among higher income groups. As against 4 per cent of households with Annual Household Income (AHI) up to Rs 6,000, 24 per cent of households with AHI Rs 30,000 and above are using clean fuels.

Eighty-three per cent of clean fuel users as well as biofuel users were drawing 3 litres of kerosene from ration. Around 30 per cent of households were buying an average quantity of 7 litres per month for cooking from the open market.

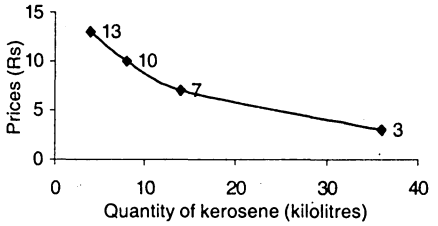
Across all the villages covered, respondent households have expressed their willingness to switch to kerosene if available abundantly at a price of Rs 2.90 (rounded to Rs 3) per litre. The additional demand of kerosene in all the sampled households is 27 kilolitres per month at this price over and above the present consumption of 9.3 kilolitres. Therefore total demand of kerosene at Rs 3 is 36 kilolitres. At the time of the survey in September 99 the ration price was Rs 3 per litre, which was subsequently increased to Rs 5 per litres in February 2000. Therefore, willingness to pay for price above Rs 6 was examined.

At the price of Rs 7/litre the demand of kerosene in the sampled households works out to be 14 kilolitres per month. Whereas, demand at parallel market rate (Rs 10/litre) of kerosene works out to be 8 kilolitres per month (see Figure 6 for demand of kerosene). There is also a demand of 4 kilolitres at Rs 13 per litre, which shows that some people are willing to pay higher than the market rate. In such a situation it is necessary to find out the reasons why people who are willing to pay are not getting it. This demand refers to only sample households in the sample villages. For all the households and all the villages, the demand could be quite large.

Table 5: Kerosene Consumption

Litres of Kerosene Per Month	House-holds	Per Cent Households Using Kerosene
Less than or equal to 3 litres	3352	69
Greater than 3 to 5 litres	384	8.4
Greater than 5 and less then 20 litres	827	18

Figure 6: Demand of Kerosene
(Kilolitres per month)



In the survey area 61 per cent households (i e, 3067 HH) are not using clean fuels. Only 38 per cent of the households are not willing to switch from the current fuel. Multiple reasons were given for not using the clean fuel. These are summarised in Table 7. Approximately 74 per cent households are of the view that it is very expensive where as 52 per cent are told that it is not always available.

This shows that in the rural areas of TN there is short supply of clean fuel. 52 per cent households are willing to switch to clean fuel if made available. Out of many options, only two reasons, viz, lack of affordability and availability stand out. Other reasons as enumerated in Table 7 are not supported by the survey in TN state.

The results of the survey reveal that only 10 per cent households are willing to spend some money to improve the air quality in the kitchen. Those who have shown willingness would like to spend as shown in Table 8. Some households were willing to have more than one improvement.

Improvement cost estimated by them to reduce smoke in the kitchen is more associated with the present living condition, i e, house type (kachcha, pucca or semi-pucca). There is a higher willingness to pay for ventilation in houses rather than for improved stoves.

The average estimated cost varies from Rs 943 to Rs 2002. As against this, they are willing to spend around half of the cost, which ranges from Rs 589 to Rs 1034 respectively for kachcha and pucca houses.

V
Housing Conditions

Housing conditions have a direct bearing on health; especially air pollution and sanitation related diseases. The relevant parameters are (a) type of house (kachcha or pucca classification of type of houses as per census), (b) number of rooms, (c) location of the kitchen, (d) type of ventilation

Houses are mostly of kachcha or semi-pucca type. It was observed in many other studies that in kachcha or semi pucca type of houses prevalence of respiratory diseases are high [NFHS 1995; Smith 1987]. Very few houses (29 per cent) are pucca houses having brick wall and concrete roofing. Figure 8 shows the distribution of type of houses in the area.

About 44 per cent of the houses have only one room (Figure 9). The number of rooms in the house is a very important information as far as the indoor air pollution is concerned. It is being observed that if there are less number of rooms in the houses chances of respiratory diseases increase because of less dispersion of the smoke. In our study also a negative correlation is observed between reporting symptoms of respiratory diseases and number of rooms.

In the sample households 21 per cent do not have any kitchen or cooking space. These households cooked their food outside in the open air. In such type of kitchen exposure is minimal for both cook and other family members, as the pollutant generated dissipate quickly in the air. The heath impact is discussed in the subsequent section of health impacts.

Thirty-three per cent households had cooking space inside the living room itself, due to which all other family members who are present during the cooking also get exposed to air pollution. 46 per cent have separate kitchen outside the house (Figure 10).

Among the separate kitchen type, 48 per cent households have tiled roofing, 34 per cent have grass, thatched or bamboo roofs. Only 11 per cent have kitchen with concrete roofing. 30 per cent of these separate kitchens have open entrance without any door. 58 per cent of kitchens are very badly ventilated, as there is no window or ventilator.

VI
Cooking Practices

Such information is very crucial for determining the exposure to air pollution due to use of biofuels of the cook and other family members who stay inside the house while cooking. The number of meals cooked determines the total exposure. Each time the fire is started using biofuels, it produces a lot of smoke and pollutants. In the same manner if cooking is performed in an enclosed area with bad ventilation and traditional stoves, exposure is much higher than cooking the meal in open air. The health impacts are discussed in a subsequent section.

Most households cooked two meals a day (74 per cent) and 15 per cent of the households cooked once. Remaining 11 per cent cooked thrice a day. The total time

Table 8: Improvements for Reducing Kitchen Smoke

Improvements/ Fitting	Number of Households	Per Cent of Households
Window/ventilator	297	59
Installation of improved chulha	186	37
Chimney	75	15
Door	85	17

Table 9: Cooking Involvement

Sex	Involvement in Cooking (Per Cent of Person)		
	Chief Cook	Partial Involvement	Not at All
Male > 15 yrs	2	5	93
Female >15 yrs	59	17	24*
Female 15- 30 yrs	45	-	

Note: * Female of age above 15 those who are not at all involved in cooking represent those women also who had cooked in past as chief cook but currently not involved due to old age or some other reasons.

Table 6: Time and Efforts for Collection of Fuel wood

Districts	Chengulpet	Coimbatore	Trichy	Tirunelveli
Villages collecting from up to 1 km	3	3	4	3
Villages collecting between 1 - 2 km	3	-	1	3
Villages collecting from 5 km or above	1	1	-	-
Average time spent per trip (hours)	2.8	2.6	2.3	2.2
Average time spent per month per household	22.4	20.8	18.4	17.6

Table 7: Reasons for Not Using Clean Fuels

Reasons	No of Households Agree	Per Cent of Households that Agree
Not always available	844	52
Expensive	1244	74.5
Scared of using	435	14
Taste of food changes	96	3.2
Wood repels for insects	93	3.1
Wood cooking helps the house	84	2.8
Wood smoke increases longevity of thatched roof	63	2.1

Figure 7: Type of House

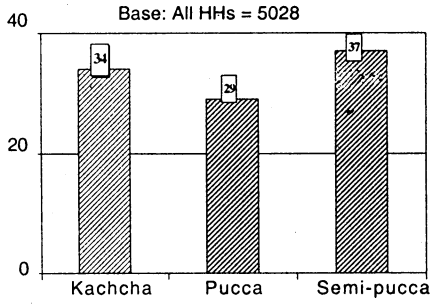


Figure 8: Number of Rooms in the House

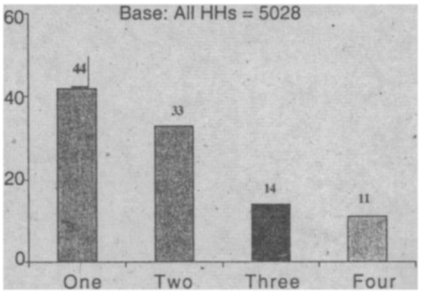


Figure 9: Location of Kitchen

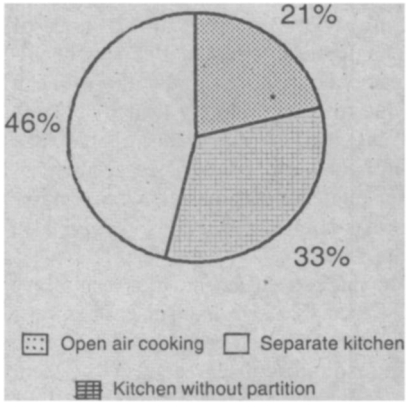
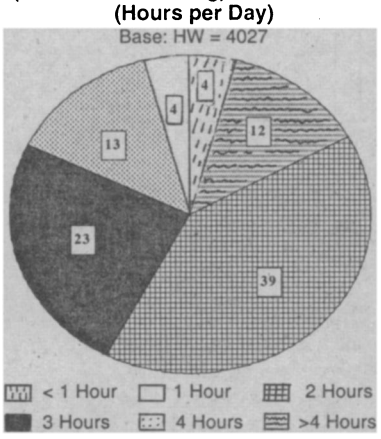


Figure 10: Time Spent by Housewives (involved in cooking) in the Kitchen (Hours per Day)



required to cook all the meals on an average was about 2 hours 45 minutes in a day. Therefore, cooks are exposed to smoky atmosphere for this long everyday.

Mostly female adults of age above 15 years are the chief cooks. Those who are chief cooks have a greater risk of respiratory ailments (see health section). On the whole males were not involved in cooking at all (see Table 9).

VII
Exposure to Indoor Air Pollution

500 rural households (10 per cent selected randomly from total sample of 5028) were surveyed with the indoor air quality monitoring and measurement equipment. The data were collected for different type of fuel and different kitchen location and stove types.

Respirable Dust Concentration

The results suggest that the average concentrations of indoor air pollutants were highest during cooking with biofuels. Personal exposure of respirable dust range from around 70 $\mu g/m^3$ for houses using clean fuels to around 2000 $\mu g/m^3$ in houses using biofuels. The concentrations at various locations during cooking with biofuels depended on the type of kitchen. Personal exposures while cooking with biofuels were the greatest in indoor kitchens without partition (1200-2000 $\mu g/m^3$), followed by indoor kitchens with partitions (1300-1700 $\mu g/m^3$), separate kitchens outside the house (500-1300 $\mu g/m^3$) and outdoor kitchens (700-900$\mu g/m^3$) (shown in Figure 12). While cooking with biofuels, concentrations in the adjacent living area were as high as personal exposure to the cook in the indoor kitchen without any partition. In some cases, the concentration in the adjacent area exceeded the personal exposure of the cook. Whereas, concentration of respirable dust in the adjacent areas was much lower than the cook's exposure in other type of kitchen (Table 10).

Therefore, location of kitchen and ventilation in the kitchen are very important determinants of exposure to other members of the household.

The carbon monoxide (CO), nitrogen dioxide (NO_2) and sulpher dioxide (SO_2) concentration were above the limit of detection only in houses using biofuels. The concentrations were the highest at <2 m from the stove (CO ~ 30 ppm, NO_2 ~ 1 ppm, and SO_2 ~ 1.5 ppm) and in the adjacent room it was highest for the indoor kitchens without partitions (Table 11).

Table 12: Facilities Available at HCs

Instrument/Facility	No of HC Have It	No of HCs where It Is Working
Blood pressure measuring equipment	9	7
Cardiograph	3	3
X-ray machine	2	1
Refrigerator	9	7
Anaesthesia equipment	3	3
Emergency light	4	4
Incubator	3	1
Pathological lab	5	4

Source: Data collected from records of HCs

Table 10: Mean Concentration of Resiparble Dust vs Kitchen Location Using Fuel Wood ($\mu g/m^3$)

Type of Kitchen	Personal Exposure	Concentration Inside the House while Cooking	Concentration Outside the House while Cooking	Concentration Inside the House while Not Cooking
Indoor kitchen with no partitions	1498	1411	215	83
Separate kitchen inside the house	1506	946	155	84
Separate kitchen outside the house	1341	461	136	73
Open air cooking	894	203	209	75

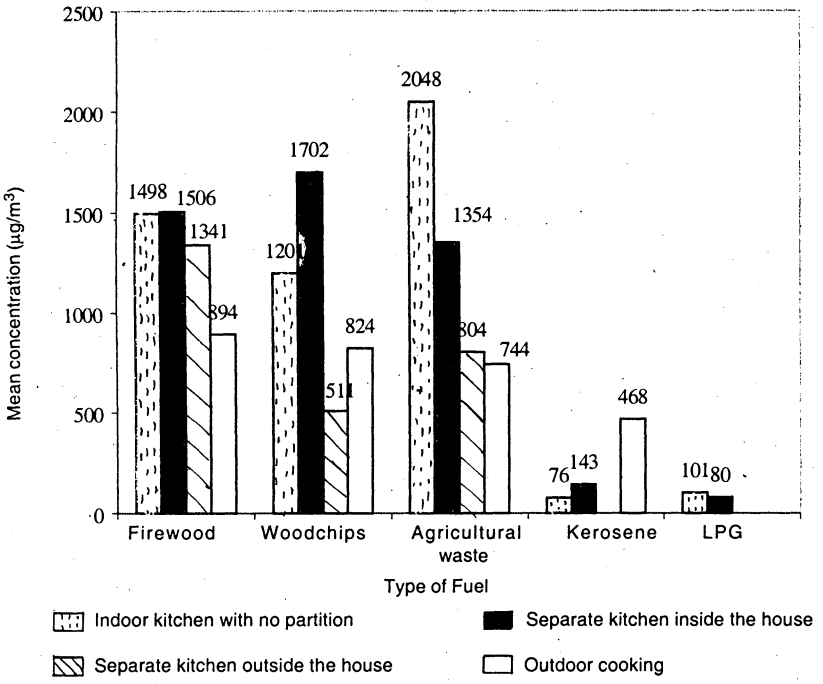
Sources: 1 IGIDR and SRMC report, 2000.
2 Parikh, J et al, 2000.

Table 11: Concentration of Gases vs Kitchen Location

Type of Kitchen	Concentration of Gases (PPM)								
	CO			SO_2			NO_2		
	1	2	3	1	2	3	1	2	3
Indoor kitchen with no partitions	31	19	5	1.6	0.6	0.2	1.3	0.4	0.1
Separate kitchen inside the house	30	12	3.4	1.4	0.4	0.3	1.1	0.3	0.2
Separate kitchen outside the house	27.5	6.8	4.6	1.8	0.3	0.1	1.4	0.2	0.2

Notes: 1 measurement <2 m from the stove inside
2 measurement >2 m from the stove inside
3 measurement >2 m from the stove outside
Source: IGIDR and SRMC, 2000.

Figure 11: Personal Exposure to Respirable Dust



The study reveals that the concentration of respirable dust is maximum when cooking is done inside the house in a kitchen without partition using biofuels in traditional stove. The exposure to chief cook is very high in all types of kitchen when cooking is done using biofuels. One of the important findings is that the individuals who are inside the house during the cooking activity too face high exposure.

The results of the study suggest that opting for good ventilation, cleaner fuels, rational cooking technology and practices can substantially reduce the level of pollution.

VIII
Health Impact

The health impacts of indoor air pollution due to use of biofuels can be attributed to exposure to domestic smoke. Since a large number of variables are involved in linking air pollution with human health, it is very difficult to prove that air pollution has a clearly demonstrable effect on human health. Many studies in the past have tried to link air pollution with respiratory diseases [Ostro 1995; Smith 1987: Smith 1996; NFHS 1995]. In this study we have tried to link health impacts with exposure to indoor air pollution and also other confounding socio-economic variables. The data were also collected for peak expiratory flow (PEF) for 12,000 individuals. PEF measures how much air and how fast one can blow out. This reflects on the lung capacity and elasticity.

As discussed earlier, data related to health status was collected through personal interviews, peak flow meter for lung function and check up by doctors of symptomatic cases and all the members present in indoor quality monitoring households. To obtain overall view of the area, data was collected from health centers (HCs) records and interview of employees. We will first have overview of health profile from selected HCs.

This information is based on the survey conducted at nine HCs servicing the villages covered in the study. Working hours for five HCs were eight hours whereas, four HCs remain open for 24 hours. Average number of doctors per HC work out to be three excluding one HC, viz, Government Head Quarters Hospital, in Tirunelveli district having 20 doctors. The instruments and facilities available in these nine HCs are listed in Table 12.

Majority of employees of HCs contacted felt that the medicine made available at health centre is quite adequate and most of the HCs do not charge any fee from the patients. Average annual operational cost of running the HC is worked out to be Rs 1.30 lakh excluding salaries of doctors. The cost of medicines being distributed free of charge worked out to be Rs 1.48 lakh approximately. The government funds this entire cost.

The records from HC reveal that three HCs received less than 50 patients in a day. Average number of patients received in a day by all 9 HCs together was 223, thus average works out to about 25 patients per HC per day. The high season on the basis of number of patients coming to HCs is from July to September.

Respondents of majority of HCs (67 per cent) have stated that there is no prevalence of a particular disease in any of the nearby villages. However, one HC has mentioned prevalence of respiratory infection in Veerapandi village of Coimbatore district and another HC mentioned about high prevalence of skin disease in Trumbucheri and Lattur villages of Chengalpattu district. In Veerapandi village prevalence of respiratory diseases can be due to brick industry near by.

Total number of patients treated in a month by these HCs for respiratory or water-related problems and average number of patients per PHCs is given in Table 13.

The patients suffering from respiratory diseases and water-related diseases appear to be quite high. The patients suffering from respiratory diseases are 27 per cent and from water-related diseases are 17 per cent of total patients treated at these HCs. The prevalence of air and water pollution related diseases are shown to give a picture of the area covered by these HCs . These HCs cover many villages along with the sample village.

To find out the pattern of respiratory disease prevalence in the area we look at patients treated in each HC in a month.

From Table 14 it is clear that prevalence of respiratory diseases is higher in the area covered by HC 3 and 4. Bronchitis is seen as most common among respiratory diseases. The numbers of patients treated at respective hospitals/health centres are from all those villages covered by that particular centre.

Self-Reported Assessment of Health

The survey data show that smoking is not prevalent in the women, whereas 23 per cent men smoke in the sample. The results of personal interview using MRC questionnaire on health status reveal that 7.4 per cent of the total population have one or the other symptoms of respiratory diseases (Table 15), whereas, 3 per cent of total population reported to have respiratory diseases.

Asthma was reported by 12 persons per 1,000 persons whereas 8 per 1,000 persons

reported bronchitis (Table 16). The reporting of symptoms and diseases were recorded on the basis of respondent's memory and recall for all the members of the households. Therefore, reliability of data for proxy responses is very little.

Incidence of asthmatic symptoms reported to be higher among those who cook inside as compared to those who cook open air. Breathlessness and chest wheezy symptoms have also shown similar trend. This trend has also been reported even for TB symptomatic cases.

Physicians' Report

Physicians examined all those who reported disease symptoms and who were present during the survey. In addition, physicians also examined all members who were present in the indoor air quality monitoring (IAQ) households even if they did not have any symptoms. The summary of physicians' checkup is given in Table 17. The report reveals that approximately 16 per cent of population are suffering from acute respiratory infection. This result is biased because the subsample, which was examined by the physicians, included mostly symptomatic cases. The physician report also reveals that prevalence of respiratory illness in men are found to be more or less same as in women.

IX
Statistical Significance of Variables with Health

To establish a linkage of health with kitchen smoke and cooking practices, it is necessary to see whether smoke from use of biofuels and cooking practices have statistically significant impact on health or not. In the subsequent section these linkages are explained.

The linkage is established using Z test and χ^2 test of significance. The formula used for Z test is as follows

$$Z=(p_1-p_2)/\sqrt{\{p^*(1_{-p})^*(n_1+n_2)/(n_1{}^*n_2)\}}$$

where p_1 and p_2 are two different proportions out of two sub-samples n_1 and n_2, and

$$p = (n_1p_1+n_2p_2)/(n_1+n_2).$$

Z follows normal distribution with mean zero and standard deviation 1. At 95 per cent confidence level the significant value of Z is 1.96. If the calculated value of Z is greater than the significant value, the null hypothesis that kitchen smoke and cooking practices have no health impacts are rejected. Prevalence ratio has been calculated as the ratio between p_1 and p_2.

On the basis of self-reported symptoms of respiratory diseases, positive linkage of eye irritation and any respiratory problem, particularly cough, phlegm, breathlessness, wheezing and blood in sputum symptoms have been observed at a broader level with the use of biofuels. These symptomatic cases have been found significantly higher among those using biofuels as compared to those using LPG. LPG and biofuel users are mutually exclusive to compare, whereas kerosene is being used along with biofuels. Therefore for testing the impact of biofuels on health it was decided to make a com-

Table 15: Self Reported Respiratory Disease Symptoms

Respiratory Disease Symptoms	No of Persons Per 1,000 Persons
Cough	32
Phlegm	31
Breathlessness	31
Wheezing	30
Blood in sputum	7
Any respiratory disease symptom	74

Table 16: Disease Prevalence on the Basis of Self-Reporting

Disease	No of Persons Per 1,000 Persons
Asthma	12
Bronchitis	8
Pneumonia	4
Tuberculosis	3

Table 13: Number of Patients per Month in 8 HCs of Tamil Nadu
(September 1999)

Disease Type	Total Patients	Average No of Patients Per HC	Percentage to Total Patients
Bronchitis	2058	257	14.5
TB	886	111	6.3
Asthma	575	72	4.1
Pneumonia	31	4	0.2
Other respiratory diseases	254	32	1.8
Total for respiratory diseases	*3804*	*476*	*26.9*
Eye disease	1456	182	10.3
Skin infection	515	64	3.6
Total	*1971*	*246*	*13.9*
Diarrhea	793	99	5.6
Total worm infection	450	56	3.2
- Round worm	260	43	1.8
- Hook worm	171	24	1.2
- Guinea worm	19	4	0.1
Malaria	46	6	0.3
Hepatitis A (Jaundice)	14	2	0.1
Fluorosis	7	1	-
Arsenic Poisoning	4	1	-
Other water related diseases	610	87	4.3
Total of water related diseases	2374	323	16.6
Grand total	8144	1043	

Source: Data collected from records of HCs.

Table 14: Patients Treated at Different HCs Suffering from Respiratory Diseases

No		Pneumonia	Asthma	Bronchitis	Tuberculosis	Other res dis	Total
1	Govt Additional Public Health Centre, Chengalpattu	-	-	-	-	-	-
2	Nerumbur Public Health Centre, Chengalpattu	5	25	15	5	3	53
3	Periyerpalayam Public Health Centre, Thiruvallur	15	150	998	20	998	2181
4	Govt Hospital, Kotur, Pollachi, Coimbatore	1	150	750	60	210	1171
5	Govt Primary Health Centre, Erisinampatty, Coimbatore	0	20	60	2	0	82
6	Pethemayakarur Govt Primary Health Centre, Coimbatore	0	5	20	0	95	120
7	Government Public Health Centre, Veerapandi,Coimbatore	0	25	15	1	150	191
8	Government Primary Health Centre, Edaikal, Tirunelveli	10	200	200	10	0	420
9	Govt Head Quarters Hospital, Thenkasi, Tirunelveli	0	0	0	156	0	156
	Total	30	575	2058	254	1456	4321

Source: Data collected from records of HCs.

parison with LPG users. The results are presented in Table 18.

Thus, symptomatic cases cough, phlegm, breathlessness, wheezing, blood in sputum and eye irritation reported are found to be significantly higher among biofuels users compared to LPG users. The prevalence ratio of any type of respiratory symptom for biofuel users compared to LPG users are higher by a factor of 1.62 for various respiratory symptoms. For eye irritation it is 1.37.

Among the biofuel category, wood being the main fuel used by most of the biofuel users, linkages of respiratory disease symptoms and fuel wood users were also observed. The result reveals that those members who are exposed to wood smoke have a very high risk of developing respiratory disease symptoms (Table 19).

Linkage of Respiratory Symptoms with Involvement in Cooking

Similar analysis with adult chief cooks using wood for cooking has shown that chief cooks have significantly higher risk for cough, phlegm, breathlessness, wheezing and blood in sputum than those who have no or less involvement (Table 20).

Symptoms of Respiratory Diseases in Kachcha/Pucca Houses

On the basis of self-reported symptomatic cases of respiratory diseases cough, phlegm, breathlessness, wheezing, blood in sputum and eye irritation are found to be significantly higher among those living in kachcha houses as compared to those living in pucca houses. This is possibly due to poor ventilation and lower ceiling height in kachcha houses as compared to pucca houses. Moreover, use of LPG is higher among the residents of pucca houses. The results are shown in Table 21.

Symptomatic Cases among Indoor and Open-Air Cooking

Self-reported symptomatic cases of respiratory diseases like cough, phlegm, breathlessness, wheezing, blood in sputum, eye irritation are also found to be significantly higher among those who cook indoors as compared to those who cook in open air. This is due to higher exposure to smoke in case of indoor cooking as compared to that of open air cooking. The results are presented in Table 22.

These results presented above reveal that exposure to biofuels smoke has significant health impact. Type of house and involvement in cooking is also a significant variable as far as respiratory disease symptoms are concerned. Prevalence of respiratory disease symptoms are significantly higher for those who cook indoor.

Linkage of Lung Capacity with Cooking Practices

All above linkages are established using subjective enquiry. An objective physical measurement for status of health for all those present were performed using peak expiratory flow (PEF) rate for measuring lung capacity. Clinically PEF measurements are primarily used to detect changes in a subject over time. Here in this study it is used as an indicator for lung capacity. This exercise was also useful to make women feel more concerned about their health as this was some thing, which they can see themselves. It had demonstration impact also. A woman when she blows a peak flow meter she can herself see the deflection on the scale and compare it with other women of the same age group.

The recorded PEF value is compared with estimated PEF value for knowing the lung capacity impairment. The estimated PEF value is calculated using following equations given by Udwadia (1987)

$$\text{PEF for males} = -6.2 - 0.0187 \text{ age} + 0.085 \text{ height}$$

$$\text{PEF for females} = -2.7 - 0.0018 \text{ age} + 0.049 \text{ height}$$

If the recorded value of PEF is below 80 per cent of the estimated value then it is considered as impairment of lung capacity. According to the lung capacity report it was found that lung impairment is high more in the case of men than women (Figure 13). The results reveal that 31 per cent of women above 15 years of age have their PEF value below 80 per cent of estimated value, whereas, in case of men above 15 years of age and non-smokers, approximately 44 per cent have lung capacity below the 80 per cent of estimated PEF. For men smokers of same age group, 46 per cent have PEF below the normal (Figure 13).

The fact that only 31 per cent females have PEF below 80 per cent of normative value compared to 44 per cent non-smoker males is some what puzzling. This is possibly due to the fact that the females in all the sample households were available for the PEF test. However, the sample

Table 17: Analysis of Physicians' Checkup Reports

Diseases	Total	Male	Female
Base	1151(100)	572(100)	579(100)
Acute Res. Infection	179(15.6)	89(15.6)	90(15.5)
Chronic Obstructive Airway	158(13.7)	83(14.5)	75(13.0)
Reversible Obstruc Airway	118(10.3)	60(10.5)	58(10.0)
Parenchymal Lung disease	55(4.8)	26(4.5)	29(5.0)
Pulmonary TB	48(4.2)	25(4.4)	23(4.0)

Table 18: Respiratory Disease Symptoms in Households Using Biofuels and LPG

Fuel used	Total Members	Symptoms Reported (Per Cent)						
		Cough	Phlegm	Breath-lessness	Whee-zing	Blood in Sputum	Any Res Symptoms	Eye Irritation
Any bio-fuel(n_1)	20553	3.33	3.22	3.24	2.03	0.76	7.64	5.04
LPG (n_2)	1630	1.41	1.84	1.60	1.17	0.25	4.72	3.68
Z-value*		4.24	3.08	3.66	2.42	2.36	4.32	2.44
Prevalence ratio		2.36	1.75	2.03	1.74	3.04	1.62	1.37

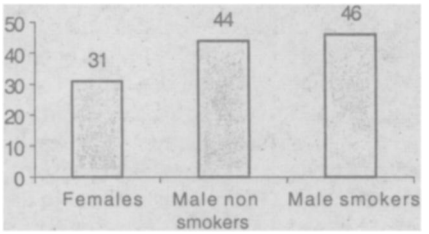
* $Z = 1.96$ corresponds to significance at 95 per cent confidence level

Table 19: Risk of Respiratory Symptoms in Fuelwood Using Households

Fuel used	Total Members	Symptoms Reported (Per Cent)					
		Cough	Phlegm	Breath-lessness	Wheezing	Blood in Sputum	Any Res Symptoms
Wood	18231	3.25	3.15	3.28	2.00	0.76	7.59
LPG	1630	1.41	1.84	1.60	1.17	0.25	4.72
Z-value*		4.1092	2.9564	3.7364	2.3373	2.3655	4.2489
Prevalence ratio		2.30	1.71	2.05	1.71	3.04	1.61

* $Z = 1.96$ corresponds to significance at 95 per cent confidence level

Figure 12: PEF Below the 80 Per Cent of Norms



of males at home is not as representative as in the case of females. As shown in Table 23, PEF was recorded for 70 per cent of females in the sample households, which includes 100 per cent chief cooks and other females, whereas, for males, the PEF was recorded only for 34 per cent of total males in the sample households. The males staying at home at the time of survey participated in these tests. It is possible that they are aged, disabled temporarily sick or sick otherwise, or temporarily unemployed or unemployed otherwise. For example, in male individual sample (Table 23) 25 per cent are smokers and 21 per cent are above 50 years of age. These numbers are zero per cent and 17 per cent respectively for female sample. If we had representative sample of males we could expect better PEF performance for males. However the numbers by themselves can be misleading and statistical significance tests are essential. These are done for males and females separately in Table 24 and Table 25.

The lung function testing reveals that incidence of PEF below the 80 per cent of normative PEF, is linked with involvement in cooking. The Z test shows that the non-smoker male chief cooks are at significantly higher risk of developing respiratory illness than those non-smoker males who are not involved in cooking (Table 24). It was difficult to get a sample of females who were not involved in cooking at all, therefore, the significance test was performed only for non-smoker males.

In most households, two meals are cooked per day. In a smaller number of households three meals a day are cooked as discussed in section 7. The results show that number of meals cooked in a day using wood has significant health impacts on females but not for males (Table 24 and Table 25). This is possibly due to the fact that males generally stay outside the house during cooking hours.

The lung function testing also reveals that the incidence of respiratory symptoms is significantly higher in kachcha houses than those in the pucca houses (Table 24 and Table 25). This shows that it is not just the smoke but also dusty households that may affect health. This is a very important confounding variable.

X
Main Environmental Concerns

To ascertain how women perceive the problem of indoor air pollution and what are their main environmental concerns, women were asked to rank their preferences. The comparison of environmental concerns is performed at different income levels. The respondents were asked to give three ranks for any of the following environmental issues, in order of their importance. These have been converted into scores by giving reverse weight. The maximum and minimum score can thus be three and one respectively. Scores thus obtained are given in Table 26.

From the above table it is clear that women perceive better water quality as the most important need across all the income levels. At lower income levels after water quality it is outdoor air that is important and sanitation comes at third place.

Table 20: Respiratory Disease Symptom to Chief Cook for Different Fuel Use

Fuel used	Total Members (Chief Cook)	Symptoms Reported (Per Cent)				
		Cough	Phlegm	Breath-lessness	Wheezing Attack	Blood in Sputum
Wood	3992	2.51	2.40	6.21	3.21	1.00
LPG	372	1.08	1.61	2.96	2.15	0.00
Z-value *		5.898	3.244	8.629	3.760	6.847
Prevalence ratio		2.32	1.49	2.10	1.49	

* $Z = 1.96$ corresponds to significance at 95 per cent confidence level.

Table 21: Health status in Kachcha vs Pucca Houses

House Type	Total Members	Symptoms Reported (Per Cent)					
		Cough	Phlegm	Breath-lessness	Wheezing	Blood in Sputum	Any Res Symptoms
Kachcha	7383	3.64	3.48	3.68	2.21	1.15	6.23
Pucca	6774	2.39	2.63	2.80	1.71	0.49	4.03
Z-value*		4.3313	2.9387	2.9414	2.1182	4.3418	5.9025
Prevalence ratio		1.52	1.32	1.31	1.29	2.35	1.55

* $Z = 1.96$ corresponds to significance at 95 per cent confidence level

Table 22: Indoor Cooking vs Outdoor Cooking

Cooking Place	Symptoms Reported (No of Cases)					
	Cough	Phlegm	Breath-lessness	Wheezing	Blood in Sputum	Any Res Symptoms
Indoor cooking and disease symp	535	522	521	331	113	1267
Indoor cooking but no disease symp	17075	17088	17089	17279	17497	16343
Open air cooking and disease symp	176	170	170	108	47	388
Open air cooking but no disease symp	4465	4471	4471	4533	4594	4253
Calculated χ^2 value	6.7550	5.9520	6.0576	3.8027	7.0828	7.2470

Standard tabulated χ^2 value at 95 per cent confidence level for 1 degree of freedom is 3.8.

Table 23: Sample Characteristics of Individuals for Which PEF was Recorded

	Males			Females	
	No	Per Cent		No	Per Cent
Characteristics of household sample			*Characteristics of household sample*		
1 Total male in the sample households > than or equal to 15 years	7831	100	1 Total female in the sample households > or equal to 15 years	8370	100
2 Age > 50 years	1359	17	2 Age > 50 years	1140	14
3 Smokers	2037	26 (of total males)	3 Smoking is not found	0	0
Characteristics of male individual sample for which PEF is recorded			*Characteristics of female individual sample for which PEF is recorded*		
4 PEF recorded	2663	34 (of total)	4 PEF recorded	5845	70 (of total)
5 PEF recorded of > 50 years	548	21 (of total PEF)	5 PEF recorded for >50 years	993	17 (of total PEF)
6 Smokers in PEF sample	675	25	6 Smokers in PEF sample	0	0

Reduction in kitchen smoke occupies the forth place. But with the increase of income the priority changes and at income levels between Rs 10,001 to Rs 30,000 per year per household sanitation is at second place followed by outdoor air quality. At higher income level of above Rs 30,000 the preference for better indoor air quality appears at third place after water and sanitation. It seems that water and sanitation are short term and immediate problems. On the other hand health effect of air pollution is a long term issue. In poor households health and inconvenience of biofuels are perceived to be of less significance.

XI Summary

Given the recent concern about indoor air pollution due to use of biofuels, a comprehensive survey is essential so that ground realities are captured and interventions are properly selected and channelised. This sector summarises preliminary results of selected indicators covering (a) socio-economic characteristics (b) fuel consumption pattern, (c) cooking practices, (d) exposure to indoor air pollutants, (e) health profile, and (f) environmental concerns. The data related to socio-economic conditions, fuel consumption pattern and cooking practices were collected from the chief cook of the household. Data pertaining to exposure to respirable dust (PM_{10}), CO, SO_2 and NO_2 were collected with state-of-the-art equipment from randomly selected 10 per cent of households. The health profile data were collected for respiratory disease symptoms using Medical Research Council 1986 questionnaire and also for water-borne diseases. Physicians examined all those reporting any symptom and present during the survey. In addition, physicians examined all members present in the indoor air quality monitoring households irrespective of symptomatic status. An objective physical measurement of pulmonary functioning was also undertaken for all those present during the survey by using peak flow expiratory meter. In all peak expiratory flow (PEF) reading for 12,000 individuals were recorded, possibly the largest reported sample size in India so far. This exercise was used to have a demonstration impact especially for women. The nutritional status (height, weight, and age) was also recorded. The analysis reveals some very important and conclusive facts.

– The survey shows that in rural Tamil Nadu most of the villages have some road net work and mode of transportation. Almost all the villages have access to primary school and health care facilities with an average of three doctors per health centres. Majority of villagers (56 per cent) are landless and about 30 per cent of the villagers are either small or marginal farmers. The income structure is such that 45 per cent of the households have average annual income less than Rs 10,000.

– Biofuels is the main source of cooking for about 96 per cent households. Use of dung cake is not very common in the area. In most of the villages the distance travelled to collect fuel wood is less than 1 km. Average consumption of fuel wood is 2.5 kg per household per day and fuel is generally gathered from the nearby forests. The average distance travelled to collect wood is about 1.5 km and in a month of 12 km is travelled by each household. Kerosene is mostly used for lighting. This is reflected by the very small amount of kerosene consumed per households, i e, 2.1 litres per household per month. Nearly 43 per cent households own kerosene pressure stoves. However, they do not get kerosene supply to use them. Almost all the villages in Tamil Nadu are electrified but our survey shows that only 26 per cent households are connected with electricity.

– What are the preferred interventions to avoid smoke? These can be fuel substitution (kerosene or LPG) or efforts to avoid smoke from the biofuels. Our results suggest that availability of clean fuels viz., kerosene and LPG is not sufficient in the area. Even in the households where kerosene is used for cooking, its use is restricted for making small meals or snacks. The reason for its restricted use is mainly non-affordability and unavailability. All other speculations often made in literature are not supported by the survey in Tamil Nadu state. Approximately 50 per cent of the population have no other option but to use biofuels due to non-availability of kerosene. Demand of kerosene at market price of Rs 10 is estimated to be 8 kilolitres per month in the sampled households. This latent demand can be tapped to reduce health impacts and drudgery of women.

– Willingness to pay for ventilation in the house is higher than for improved stoves. As 59 per cent households are willing to go for improving ventilation whereas, only 37 per cent are willing to install improved chulha. Only 10 per cent

Table 24: Statistical Analysis of PEF Test Results for Non-smoker Males

	Cooking Involvement		Meals Cooked Per Day with Wood		Type of House	
	Chief Cooks	Not Involved	3 Meals	2 Meals	Kachcha	Pucca
Below 80 per cent predicted PEF	70	749	70	446	537	189
Total Number	115	1786	153	1082	1058	535
Percentage	61	42	46	41	51	35
Z value*	3.33		1.19		6.15	

* *Z = 1.96* corresponds to significance at 95 per cent confidence level.

Table 25: Statistical Analysis of PEF Test Results for Females

	Meals Cooked Per Day with Wood		Type of House	
	3 Meals	2 Meals	Kachcha	Pucca
Below 80 per cent predicted PEF	136	906	1159	407
Total Number	402	3004	3388	1488
Percentage	34	30	27	34
Z value*	2.0		5.0	

* *Z = 1.96* corresponds to significance at 95 per cent confidence level.

Table 26: Main Environmental Concerns

Environmental Concerns	Income Levels				
	=<5000	5001-10,000	10,001-20,000	20,001-30,000	>30,001
Better water quality	2.38 (1)	2.57 (1)	2.29 (1)	2.32 (1)	2.34 (1)
Better outdoor air	2.01 (2)	1.97 (2)	1.92 (3)	1.95 (3)	1.87
Better sanitation	1.84 (3)	1.98 (3)	2.11 (2)	2.03 (2)	2.05 (2)
Reduced kitchen smoke	1.74	1.78	1.78	1.89	1.89 (3)
More forest around the village	1.56	1.59	1.60	1.58	1.61
More grazing area around	1.51	1.40	1.51	1.4	1.44

Figures in parenthesis are order of the scores.

of households are willing to spend money to improve air quality in the kitchen per se. Our study with a small sample in Tamil Nadu where indoor air quality was measured (Parikh et al) showed that kitchen location and partition wall are also important variables.

– The health centres study reveals that there is prevalence of air and water pollution related diseases in the area. The high season for these diseases are from July to September.

– In the study area most houses are kachcha or semi pucca type (71 per cent, n= 3570) and about 44 per cent houses have only one room. Location of the kitchen in 33 per cent houses is inside the living room itself. 46 per cent households have separate kitchen. 30 per cent of these separate kitchens have open entrance without any door. Most of the households (74 per cent) cook twice a day. Total time required to cook all the meals on an average is about 2 hours 45 minutes. Mostly females of age 15 to 45 years are the chief cooks.

– The monitoring of indoor air pollution exposure with personal samplers reveals that the cooks using biofuels for cooking are exposed during cooking to very high level of respirable dust (PM_{10}) whether the cooking is done in open air or indoors using any type of stoves. The magnitude of exposure ranges from 894 to 1498 $\mu g/m^3$.

– The study further reveals that those who are not the chief cooks but stay inside the house while cooking are also exposed to unexpectedly high levels. Some times their exposures are higher than the chief cook. For this population, mainly the sick, elderly and children the location of kitchen is very important determinant of the exposure levels. As the results show that the concentration of PM_{10} decreases sharply from approximately 1200 $\mu g/m^3$ to 200 $\mu g/m^3$ with the change in the location of kitchen from indoors to open air cooking.

– The data further reveals that on the basis of self reported (5028 cases) and proxy responses (17,200) about symptoms of respiratory illness, men were found to be suffering more or less same from the respiratory symptoms than the women.

– The linkages of health with biofuel use were also established on the basis of self-reported symptoms of respiratory diseases. The symptoms of cough, phlegm, breathlessness, wheezing, etc, are significantly high in case of households using biofuels than the households using LPG. Even eye irritation is also found to be significantly high in biofuel user households.

– The respiratory symptoms are significantly higher in biofuels using households who cook indoors than those who cook outdoors.

– On the basis of self reported and proxy responses, respiratory symptoms are significantly higher among all members of households living in kachcha built homes as compared to prevalence in pucca homes.

– The testing of lung capacity further reveals that the involvement in cooking and number of meals cooked in a day using wood have significant health impacts.

– The incidence of PEF below expected (normative) PEF is significantly high in kachcha type of houses than the pucca type. This shows that it is not just the smoke but also the dusty kachcha households that may affect health. Data on symptoms further support this.

– In the survey area women place the highest priority on water quality across all the income levels followed by sanitation. It seems that water and sanitation are short term and immediate problems. On the other hand health effect of air pollution is a long term issue. In poor households health and inconvenience of biofuels are considered to be less significant.

More rigorous statistical analysis is underway to examine number of variables and their relationships for four states viz, Rajasthan, Himachal Pradesh, Tamil Nadu and Uttar Pradesh. However, we wish to report on the preliminary analysis of Tamil Nadu, as to increase awareness about the database to those who are interested in these issues.

Comprehensive data collected during the survey also describe the health effects and interrelationships among variables covering water supply, sanitation facilities, standard of living and the overall household environment. Further analysis is being carried out to inter connect the above issues. Similar surveys are also being carried out in northern India covering Himachal Pradesh, Rajasthan and Uttar Pradesh. The preliminary analysis of data is going on. EPW

Appendix Notes

1 For monitoring RSP concentration: Area/personal samples for respirable dusts were collected and analysed according to NIOSH protocol 0600. According to the method, samples were collected using a 10-mm nylon cyclone equipped with a 37mm diameter poly-vinyl-chloride (PVC) (pore size 5fm) filter at a flow rate of 1.7 litres/miniute. Air was drawn through the cyclone pre-selectors using battery operated constant flow pumps supplied by SKC Inc.

2 For monitoring Gas Concentrations: Concentrations were determined using portable data-logging electrochemical multi gas detectors manufactured by Quest Technologies Inc. The minimum level of detection was 1 ppm for carbon monoxide (resolution of 1 ppm, range 1-999 ppm) and 0.1 ppm for SO_2 and NO_2 (resolution 0.1 ppm, range 0-50 ppm).

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