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Patterns of Domestic Air Pollution in Rural India

Jamuna Ramakrishna

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PATTERNS OF DOMESTIC AIR POLLUTION IN RURAL INDIA

by

Jamuna Ramakrishna

This book is dedicated to

my parents:

Sharada and Venkataram Ramakrishna

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ABSTRACT

Domestic air pollution in rural India results mainly from the burning of biomass cooking fuels; pollutant levels are determined by a number of factors that are cultural, technological, and environmental in nature. Chief amongst these are stove, fuel, and ventilation. This study investigates these and other parameters affecting domestic air pollution in one north Indian and two south Indian villages with the object of relating the cultural and environmental distinctions between these settings to the observed levels of air pollution exposures. The study also evaluates the effectiveness of improved cookstoves in reducing exposures.

Data were gathered on air pollution exposures by using personal monitoring devices; survey questionnaires were used to collect information on fuel use patterns and preferences, cooking practices, and perceptions of domestic air pollution. The first provided a quantitative indication of the magnitude of exposures and the second gave qualitative information essential for understanding the realities of the situation, that is, the obstacles to change as well as the opportunities for action.

Air pollution exposures proved to be very high in all households regardless of the type of stove in use. Improved cookstoves did not consistently produce statistically significant reductions. Certain characteristics of kitchen construction and location proved important in determining exposures but the effect of several other variables such as fueling rate remains unclear. This uncertainty may be resolved if future field studies are designed to compensate for the high degree of variability in the data. The present design showed the need for large and carefully stratified samples.

The study also showed the importance of customizing dissemination programs to suit the cultural and resource characteristics of a given area. There can be no standard dissemination program just as there is no universal stove design. While an uniform dissemination strategy cannot be recommended, program design should be guided by the spatial variations in diet, cooking practices, fuel base, and financial ability within the project area. Measures that may increase the success of dissemination that have been tested in other development and health projects include increasing the participation of intended users and establishing pathways for feedback between stove designers, extension workers, and users.

While domestic air pollution is not the most urgent issue in rural India today, it is symptomatic of larger underlying problems. It brings together problems of development and environmental quality in rural areas that cannot be addressed in piecemeal fashion. At the same time, the specificity of causes implies that proposed solutions must be sensitive to the particular characteristics of place and region.

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Chapter 1

INTRODUCTION, LITERATURE REVIEW, CONTEXT

"Plus ca change, plus c'est la meme chose."

Today's is a rapidly changing world: new technologies and new applications crowd the city. Towns are only a step behind, and even the village is not what it used to be. In fact, it has been argued that the urban/rural dichotomy is no longer valid; such distinctions seem to fade as circuitous linkages pull even the remote backwaters of the world into the global economy (McGee, 1987). This is the way the world appears to those living in urban centers where evidence of this vast network can be witnessed daily.

Not all the world is readily swept into this maelstrom of progress. There is resistance in many quarters and nowhere is this more apparent than in the rural Indian kitchen. Observes Agarwal (1986), "it is noteworthy that in the heart of India's green revolution, viz Punjab, while there have been considerable improvements in the technology handled by men, in the form of tractors, threshers, combines, etc., there has been little improvement in the women's kitchen apparatus, even in the economically well-off families." And, indeed, one is struck by the aura of timelessness particularly in rural south Indian kitchens where the spatial arrangement of stove and cooking paraphenalia, and the design of the stove has not altered in centuries, the cooking utensils have been passed on from one generation of cooks to the next, and the kitchen is still the center of family life as well as, on occasion, of social and religious activities. Perhaps the fact that the rural kitchen is often the woman's domain while economic decisions are likely to be the prerogative of male household members does inhibit innovation. The different rates of progress in education between males and females may also play a role. Perhaps, too, cooking habits and diet are deeply rooted and require extraordinary circumstances and incentive to change.

In any case, it remains true that most people in the world today cook as they have done for centuries, on simple mud stoves, not much more than shielded fires, and burn unprocessed biomass fuels such as wood, animal dung, and crop residues. This is not an insignificant statistic though the energy value of the fuel involved (in tons of coal equivalent, for example) may not be impressive. Seventy-five percent of the human population depends on this fuel and these modes of cooking. In India, 60 percent of all rural energy use is for cooking purposes, larger even than the inputs to the agricultural sector (CSE, 1982). Most of the biofuels are gathered rather than bought and the proportion of crop residues and dung being used seems to be increasing. The wood that is used is in the form of twigs and brush; logs are seldom burned.

The amount of time spent in fuel collection and cooking varies widely from place to place. These basic survival activities, including water collection, occupy a major portion of every day in some parts of the world (Smith, 1987b). Such is not the case yet in India save perhaps in the Himalayan foothills and parts of Rajasthan. Nevertheless, cooks may spend three to four hours daily at the stove and one to two hours gathering fuel.

In the past such conditions ceased to exist gradually but almost automatically as the economic benefits of industrialization were realized and fossil fuels were adopted widely. Now it appears that such a transition is neither assured nor feasible in the short-term for the majority of the world's rural households. Fossil fuels are no longer cheap and easily available as they were during the industrialization of what are now called more developed countries. There are no indications that this state of affairs will change in the immediate future. The transition to cleaner, more efficient fuels will have to be delayed for quite some time (Smith, 1987a).

The burning of unprocessed biofuels in simple, unvented cookstoves causes poor air quality in the cooking area. Many anecdotal accounts have noted the smokiness of rural Indian kitchens in the past and related various health problems to the smoke (Chandra, 1964; Raju, 1953) but until recently there had been no systematic investigation of the dimensions of the problem. The need for such work is clear considering that the reliance on biofuels will continue in the forseeable future and preliminary field studies indicate that household cooks are exposed to high concentrations of various pollutants. The nature of these pollutants and their health effects are not well-known despite the long experience humans have had with these fuels. Both policy makers and the general public have been inclined to deemphasize the associated health hazards because of this familiarity but the air pollution literature shows that this complacence is, in fact, unwarranted. Rather, the available epidemiology and health statistics indicate that there is reasonable cause for concern.

Since there has been so little systematic study, basic information regarding geographic and seasonal variations in exposures is lacking. Questions that require answers include: What is the extent and severity of exposures? Are they restricted to certain populations, places, or seasons? What ameliorative action can be or has been taken? How effective have these measures been?

This dissertation addresses these issues in the rural Indian context. The conditions in one north Indian and two south Indian villages are used as illustrations. Field sites were chosen in north and south India with the aim of exploiting the cultural contrast in order to highlight the differences in the pattern of domestic air pollution. Broadly, this dissertation seeks to relate the cultural and environmental characteristics to the observed pattern of domestic air pollution. More specifically, this dissertation examines the effectiveness of one solution to domestic air pollution, the improved cookstove. Measurements of the cook's exposure to and kitchen concentrations of two indicator pollutants were taken in households using different stoves and fuels in a variety of kitchen arrangements. Using these data, information on fuel utilization, and the cooking-related characteristics of each place, the dissertation tries to identify cultural, environmental, architectural, and policy factors that influence the pattern of domestic air pollution and to arrive at an estimate of their relative influence. The major factors investigated are stove type, fuel type, kitchen location and construction materials, and cooking process and practices; the emphasis is on stove type.

Improved cookstoves appear to be the logical short-term solution to domestic air pollution and may have some beneficial effects by increasing fuel efficiency. Improved cookstove programs are being implemented widely by governments and non-governmental organizations in south Asia and in other developing regions. In light of these circumstances, the importance of the following questions becomes evident: How effective (limited here to effectiveness in reducing domestic air pollution) are these improved cookstoves in the field? What determines their effectiveness? How may their performance be improved? These questions form the focus of the dissertation; two improved cookstove programs with different objectives and dissemination strategies are compared to help in finding some answers. These programs, their structure, strengths, and weaknesses are discussed in Chapter 5.

Improved Cookstoves in India

Cookstoves come in various shapes, sizes, and materials. In India, the major differences between traditional and improved stoves are that the latter usually have enclosed combustion chambers, dampers are sometimes included to allow the user greater control over the rate of burning, and flues are often provided to remove smoke from the immediate vicinity of the cook. In addition, provision for multiple cooking pots is made in some improved cookstove designs and baffles may be installed to improve the efficiency of heat transfer. Finally, traditional stoves are almost invariably mud constructions whereas improved cookstoves are frequently metal or ceramic. The improved cookstoves in the study areas were, however, both mud stoves. Improved cookstoves, then, are generally designed to achieve higher efficiency and in some cases also to reduce air pollution in the cooking area.

It is, unfortunately, entirely possible to increase efficiency and simultaneously increase emissions or, conversely, reduce emissions and decrease efficiency as well. This is because of the way in which the two components of overall thermal efficiency, combustion efficiency and heat transfer efficiency, interact. Most improved cookstove designs enclose the combustion chamber so as to increase heat transfer efficiency. This has the concurrent effect of reducing air flow and hence combustion efficiency because of poorer turbulence and a lower air:fuel ratio. Therefore, the net result can be elevated overall thermal efficiency as well as emissions (Ahuja et al., 1987; Smith , 1987b).

This is a difficult tradeoff to deal with and one that many improved cookstove programs have found troublesome in the past. To briefly review improved cookstove history in India, Smith (1987a) identifies three main periods which reflect evolving foci and technology. The early period which is termed the Classic Period was characterized by a concern for better hygiene in rural kitchens and the stoves developed during this period were "smokeless" in the sense that the smoke was removed from the cooking area by means of a flue. The designers employed intuition rather than perceptive engineering supported by reliable data in their work (Prasad, 1983) and the dissemination programs were often organized by non-governmental organizations concerned with women's welfare or rural development. The 1970s, the oil embargo, the ensuing energy crisis, as well as the increasing concern regarding deforestation brought an awareness of the need for energy conservation. This second period, called the Energy Period, saw the development of stoves that had increased fuel efficiency. These designs were, in general, sounder technically and underwent laboratory testing. Most of the Energy Period stoves did not emphasize smoke reduction. The present generation of the stoves, developed in the Phoenix Period, are based on an amalgamation of concerns. Besides improved efficiency, these stoves are designed to achieve one or more of the following: health improvement, time savings, convenience, or improvement in the quality of life. The major tangible goals are increased fuel efficiency and reduced exposures.

There are almost as many improved cookstove programs as there are improved cookstoves. They differ in objectives, approaches, organization, and basic philosophy. They vary in magnitude from the national and state improved cookstove programs (which intend to install an improved cookstove in every rural household) to small pilot programs run by research institutions to test and improve the viability of their stove designs in the field. Somewhere along this continuum lies the third major group involved in improved cookstove dissemination, the non-governmental or voluntary organizations which frequently include improved cookstove dissemination among their other activities.

It is estimated that by March 1987 three million improved cookstoves had been built under the National Program on Improved Cookstoves in India (Garg, 1987). There are innumerable smaller programs. Though compendia of improved cookstove designs are available (TERI, 1981; de Lepeliere et al., 1981), a similar compilation of dissemination programs has not been made so no accurate figure can be given of the number of programs operating at present. In terms of the number of stoves installed, the National Program on Improved Cookstoves is certainly the largest and most active program. Some non-governmental organizations have installed large numbers of stoves over a considerable period of time. A good example of one such organization is the Gandhiniketan Ashram in Madurai, Tamil Nadu. Between 1974 and 1984 it produced and sold 12,000 stoves (Stewart and Young, 1984).

Although improved cookstoves have been frequently promoted in the past on the strength of their smokelessness, the actual reduction in domestic air pollution as a result of their introduction had not, until recently, been documented. The focus of dissemination programs and of air pollution research, in general, has been elsewhere. Information regarding air pollution in rural areas of developing countries is almost non-existent and data on indoor or domestic air pollution are scarcer still. This is partly a function of the focus of air pollution research which has been almost exclusively urban, industrial, and outdoor. This, in turn, is related to the limitations of the instrumentation available until about 10 years ago.

Patterns of air pollution

Air pollution has traditionally been studied, by geographers and others, in centers of urban and industrial growth where it has been seen as a phenomenon concomitant with economic development. The focus of these studies has been air pollution in occupational and public (outdoor) settings. Only lately has attention turned to domestic and indoor settings. Accompanying this change has been the realization that air pollution is also an important problem in rural areas of developing countries where biofuels rather than fossil fuels are the primary energy source for most processes and activities (Smith et al., 1983).

Most of the air pollution sampling done to date has been in urban industrial outdoor settings where concentrations of critical pollutants have been measured on the tops of public buildings and on street corners. The usefulness of these measurements for estimating health impacts has been increasingly questioned. Air pollution can be measured at various points: the emissions (unit of pollutant produced per unit weight of fuel burned) can be monitored at the source, or the concentration (unit of pollutant present per unit volume of air) in a specific environment, or the exposure (concentration over time) to an individual in a particular environment, or the dose (unit of pollutant inhaled or absorbed by the body). Figure 1 illustrates the relationships and distinctions between these points. If the object of the enquiry is to relate air quality to health effects, as is usually the case, then the point of measurement must be chosen with that in mind. Measuring ambient air quality does not give an accurate estimation of exposure or dose since most people spend most of their time indoors (Szalai, 1972; Michelson, 1979).

In rural areas of developing countries a larger portion of time is maybe spent outdoors but, as shall become evident, certain indoor environments in these villages can be so smoky that they dominate the exposures of individuals who must work in these environments, obscuring the influence of ambient levels.1 Clearly, in both more developed and in developing countries, a better measure of exposure than that provided by the measurement of ambient air quality alone was needed. Pollutant concentrations vary spatially and temporally and people's activity patterns affect the exposures received. Total exposure assessment, at least in conceptual form, is comprehensive in nature and takes these variations into consideration (Ott, 1985; USNAS, 1985). The basic premise is that exposure of a population cannot be extrapolated from a single micro-environment or from ambient measurements alone (Budiansky 1980). Following this shift in focus, many studies were done in which indoor air quality was monitored. A classic example is the survey by Repace and Lowrey (1980) which measured pollution levels in a variety of indoor environments ranging from offices to restaurants and homes. They found that pollutant levels were high, especially when smokers were present and concluded that previous studies that had calculated exposures based on ambient readings had probably reported underestimations. Subsequently, more detailed time budget studies and further monitoring of indoor air quality has led to a redefinition of both "exposure" and "environment."

This progression of thought is best represented in medical geography by the work of Armstrong (1973, 1976) who has studied the "specific environment" within which exposures occur. By this method, an indirect estimate of the population's risk is derived by determining its exposure to a specific environment rather than

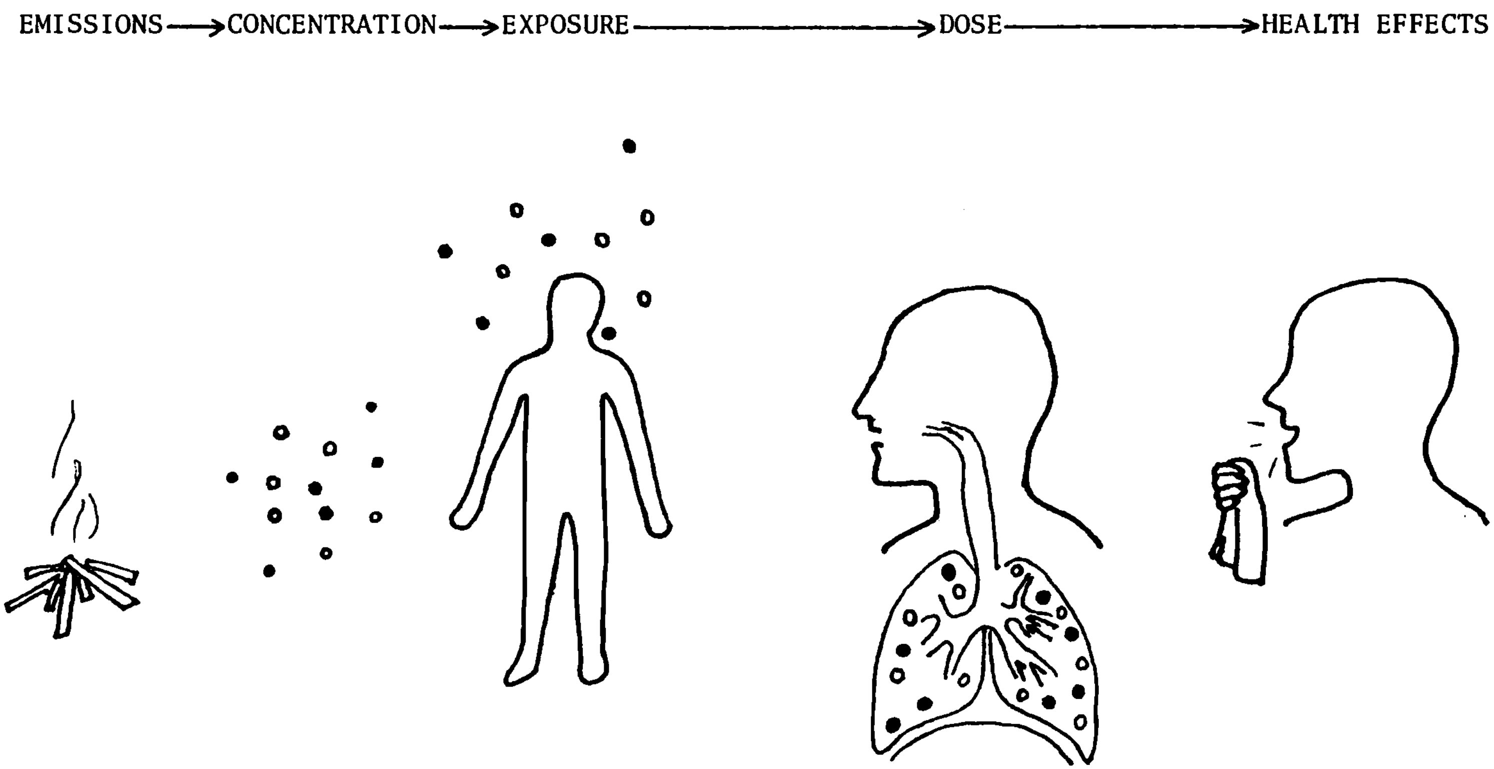


Figure 1. The points at which air pollution can be described, measured, and controlled (Adapted from Smith, 1987b)

by measuring its exposure to a hazard within or related to that environment. Itis a place-centered index of environmental quality, paralleling the indirect estimation of personal exposure in total exposure assessment though the latter usually includes area monitoring as well as the keeping of activity logs. Each approach has its uses and special qualities. The advantage of the specific-environment approach is that it is inexpensive relative to direct personal monitoring in the breathing zone and is useful in situations where the relationship between exposure and risk is well-established, but the population at risk remains unidentified. The main disadvantage is that it does not give a direct measure of exposure. It is, however, sensitive to the inter-relationships between population, behavior, and habitat. If the "specific environment" of the kitchen or cooking area were adequately characterized, for example, then it is conceivable that extensive field measurements of exposure would not be necessary, simply an accounting of the amount of time spent by individuals in that specific environment.

Related to this, the need for time-budget studies especially in developing countries has become clear. Little is known of how rural women in developing countries spend their time, where it is spent, or in what activities. As the few studies done so far show, the results can be surprising. Table 1 summarizes the findings of time-budget studies in several parts of India. A major portion of every day is spent in collecting fuel and water and cooking food, ranging from 1.5 to 6 hours/day with an average of 3.8 hours/day. These figures are relevant for planning development programs which often make assumptions regarding alternative uses of time, and, in the context of this dissertation, for determining the exposures of a large section of the rural population to the various pollutants produced during the combustion of biofuels.

There have not been many field studies of indoor air quality in rural areas of developing countries. The earliest field studies were done in Kenya and Papua New Guinea and measured concentrations of total suspended particulates (TSP) and polycyclic organic matter (POM) (TSP only in the case of Papua New Guinea) within huts where open wood and cowdung fires were kept burning for much of the day and night for space heating and cooking (Hoffmann and Wynder, 1972; Clifford, 1972; Cleary and Blackburn, 1968; Anderson, 1975). The concentrations found were extremely high, on the order of 1.5-7.8 mg/m3 in Kenya and 5-10 mg/m3 in Papua New Guinea. Table 2 gives global and Indian standards which are used for comparison in the absence of convenient alternative points of reference. Some years later, the National Institute of Occupational Health made measurements of TSP, sulfur dioxide (SO2), and nitrogen dioxide (NO2) concentrations in kitchens where biofuels were being burned in traditional stoves. They found that TSP levels were much higher than the SO2 and NO2 levels (INIOH, 1980) (Table 3). More recently, Menon (1988) has studied the diffusion of pollutants within village homes.

The first field study of exposure was conducted in 1981 in the western Indian state of Gujarat. This pilot study measured the exposure of cooks to TSP and the concentration of carbon monoxide (CO) in the cooking area. In addition, the TSP filters were analyzed for BaP (Smith et al., 1983). The findings confirmed previous hypothetical calculations that village cooks are, indeed, exposed to high pollutant levels on a regular basis (Smith et al., 1981). There was no statistically significant difference between TSP exposures or CO

Table 1. Summary of Time Budget Studies from Various Parts of Rural India

Place	Time spent (hours/day) Cooking	Fuelwood collection	Fetching water	Reference
Uttar Pradesh				Agrawal, 1981
Patharhat	1.5		1.2	
Hariharpur	4.3		1.2	
Hazipur	5.1		1.0	
Pindari	6.4		3.8	
Naraich	3.3		3.9	
Gujarat (4 villages)	2.9			Smith et al., 1983
Karnataka				ASTRA, 1982
Arjunahalli	4.2	0.4	1.2	
Hanchipura	3.8	0.8	1.4	
Keelara	3.6	0.5	1.2	
Pura	3.0	0.9	1.3	
Sugganahalli	3.2	0.6	1.3	
Ungra	4.3	0.5	1.0	

Note: Absence of figures denotes that data were not gathered. Keelara (in bold letters) was one of the field sites for the present study.

Table 2. Indian and Global Air Quality Standards

	India[a]			WHO	U.S.	
	Area A	Area B	Area C		Public	Occupational
TSP (mg/m3)						
Daily mean				0.1-0.15	0.25(0.18)[b]	
Eight-hour mean	0.5	0.2	0.1			5.0
CO (mg/m3)						
Eight-hour mean	5	2	1	10	10	50
One-hour mean				40	40	

[a] Area A = industrial and mixed use; Area B = residential and rural; Area C = sensitive areas such as tourist resorts, national parks, animal sanctuaries, hill stations, and national monuments.
[b] Proposed U.S. inhalable particulate standards.
Based on Smith, 1987b.

Table 3. Air Quality Measurements in Kitchens Where Various Biofuels are in Use

Cooking fuel	TSP (mg/m3)	SO2 (mg/m3)	BaP/TSP (mg/g)
Cow dung	16 (9.6-20)	0.24 (0.29-1.1)	0.56 (0.21-0.74)
Wood	7.2 (4.7-11)	0.17 (0.02-0.79)	0.19 (0.15-0.22)
Wood and cow dung	21 (10-58)	0.27 (0.03-1.3)	0.53 (0.07-1.7)

Source: INIOH, 1980; Aggarwal et al., 1982.

concentrations between traditional stoves and improved cookstoves (Smith, 1987b) (Table 4). People cooked indoors invariably but ventilation conditions did vary over the year since, during the monsoon season, skylights and openings in the walls and roof of the kitchen were blocked. Smith et al. (1983) found extremely high TSP exposures (peak of 56 mg/m3) under these conditions. The seasonal variations in exposure, then, can be quite substantial.

Reid et al. (1986) worked in two middle-hill villages and one higher-elevation village in Nepal where improved cookstoves have been introduced. They found statistically significant reductions in both TSP exposures and CO concentrations in households where the new cookstoves were in use. In these areas of Nepal, two types of traditional stove are in use: the agena (open fires) and the chula (enclosed fireplace). Reid et al. found that the improved cookstoves reduced TSP exposures by a factor of 3.5 when compared to agenas and by a factor of 2.3 compared to chulas. Carbon monoxide concentrations were even more drastically reduced (factors of 3.6-5.6). Table 5 summarizes the results of this study.

Table 4. Comparison of Smoke Exposures to Cooks Using Traditional and Improved Cookstoves in Two Gujarati Villages [a]

	Traditional		Improved		
Pollutant	n	mean	n	mean	p[b]
TSP (mg/m3)	21	6.4	14	4.6	n.s.
BaP (ng/m3)	21	3700	14	2400	n.s.
BaP/TSP (ug/m3)	13	830	8	570	n.s.

[a] Data taken in dry winter season by Smith et al., 1983.
[b] Two-tailed T-test based on calculations using sample statistics. n.s. = not significant, i.e., p<0.05.
Source: Smith, 1987b.

Table 5. TSP Exposures and CO Concentrations in Two Nepali Villages During Cooking with Traditional and Improved Cookstoves

	Traditional	Improved	p
N	22	27	
TSP exposure (mg/m3)	3.1	1.1	<0.05%
Coefficient of variation	84%	61%	
N	27	26	
CO concentration (mg/m3)	410	92	<0.01%
Coefficient of variation	70%	170%	

Source: Reid et al., 1986.

Joseph et al. (1985) also worked in Nepal but in simulated cooking conditions. Their area monitoring of CO during cooking using improved and traditional cookstoves showed CO levels to be lowest in homes with well-installed and maintained improved cookstoves with flues (100 ppm), as compared with all improved cookstoves (400 ppm) and traditional stoves (600 ppm).

Boleij et al. (1987) measured concentrations of respirable particulates and nitrogen dioxide in 36 households in Kenya where cooking was done on open fires using firewood as fuel. They found a mean particulate concentration of 1.4 mg/m3 and NO_2 levels of 90 ppb. Analysis of variance showed no correlation between pollutant concentrations and housing characteristics. The homogeneity of the study area may have contributed to the apparent lack of correlation.

Finally, Smith and Durgaprasad (1987) collected TSP exposure and CO concentration data in homes with and without improved cookstoves in Gujarati villages (Table 6). The TSP exposure data show that there are no obvious reductions in mean exposures experienced by cooks using improved cookstoves compared to their neighbors using traditional stoves. In fact, though not

Table 6. TSP Exposures and CO Concentrations in Gujarati Villages During Cooking with Traditional and Improved Cookstoves

	Traditional	Improved	p[a]
N	21	23	
TSP exposure (mg/m3)	3.6	3.9	n.s.
N	27	30	
CO concentration (mg/m3)	140	50	<0.05%

[a] Two-tailed T-test based on calculations using sample statistics. n.s. = not significant, i.e., p<0.05.
Source: Smith and Durgaprasad, 1987.

statistically significant, the means show a reverse trend. The near-stove CO concentrations, however, do show a significant improvement ($p<0.05\%$). Mean concentrations decreased by a factor of 3.2 (34 mg/m3 compared to 110 mg/m3). As well, the variability of mean concentrations was substantially reduced. Smith and Durgaprasad (1987) also used passive monitors to measure formaldehyde (HCHO) and nitrogen dioxide (NO_2) concentrations. There were too few monitors to make unequivocal statements but both kitchen and bedroom HCHO means were lower in homes with improved cookstoves, a trend shown only by kitchen NO_2 values. There seemed to be no clear difference between kitchen and bedroom values within each house type. A comparison with WHO guidelines suggests that these two pollutants by themselves are probably not as significant as TSP as causes of ill health.

Evidence on the Health Effects of Exposure to Biofuel Smoke

The implications of these field data for health, environmental quality, and future action are many. The health implications are difficult to estimate because most epidemiological research has focused on the health effects in urban populations of exposure to air pollution resulting from fossil fuel combustion. Though many of the pollutants produced during fossil fuel and biofuel combustion are the same there are some important differences. In particular, SO_2 is not a significant component of biofuel smoke, whereas it is of fossil fuel smoke. Most of the health effects literature treats TSP in tandem with SO_2; it is difficult to extract from this information the probable effect of exposure to TSP alone. In addition, the nature of the exposures studied has been different from those experienced in the developing-country situations of interest here. In general, chronic exposures to low pollutant concentrations or acute exposures to high pollutant concentrations such as might occur during air pollution episodes have been investigated. In contrast, the exposures occurring in rural kitchens are chronic exposures to the combustion byproducts of biofuels rather than fossil fuels, and resembling occupational rather than public exposures. There is little direct evidence on the health effects of these sorts of exposures. The literature is largely anecdotal and speculative. The few studies done so far have focused on characterizing the exposure rather than on investigating its effects. Further, researchers have not attempted to measure and correlate both exposure and health effect. Only two studies have approached such integration and used time spent in the kitchen as a surrogate measure of exposure. The first study correlated exposure with the prevalence of chronic bronchitis (Pandey, 1985) and the second with the incidence of acute respiratory infections (ARI) (Pandey et al., 1985b). There is much indirect evidence and lessons can be drawn from the literature on fossil fuel combustion byproducts and tobacco smoke. (Biofuel smoke and tobacco smoke share many similarities in composition). The vastness of this literature and the number of caveats that apply to any extrapolations make the use of indirect evidence onerous. As well, this indirect evidence has been reviewed and assessed recently (Smith, 1987b; Smith and Ramakrishna, in press) and so shall not be repeated here. Instead, the direct evidence will be presented in summary, organized by geographic area.

India: Padmavati and Arora (1976) studied the incidence of chronic cor pulmonale (heart disease secondary to lung disease) in hospital patients in Delhi over a period of 15 years. They found the incidence to be similar among men and women inspite of the fact that 75 percent of the male patients smoked while only

10 percent of the female patients did. Normally, the incidence of chronic cor pulmonale follows the pattern of smoking. In discussing this anomaly, Padmavati and Arora (1976) observe:

> The women are...exposed to smoky primitive fireplaces from childhood...
>
> Incomplete oxygenation of animal dung cakes leads to production of carbon monoxide, carbon dioxide, nitrogen dioxide and sulfur dioxide, some of which are respiratory irritants. Wood and coal used in these fireplaces are just as smoky. Exposure to such fumes eventually leads to lung damage and frequent respiratory infections, mostly untreated because of poverty and lack of medical aid. Right ventricular hypertrophy and heart failure result. Exposure to such fumes in girls and women must be considerably greater than in men.
>
> From this study it appears that in Delhi domestic air pollution is probably the cause of the higher prevalence of cor pulmonale in women than in men and the early exposure of the younger age of onset.

Other observers have made similar comments about the incidence of chronicbronchitis in rural areas and have attributed the unexpectedly high rates among women to exposure to smoke from cookstoves or heating fires (Wig et al., 1964; Vishwanathan, 1964).

Nepal: Nepal lends itself to the study of the health effects of exposure to biofuel smoke not only because these fuels are widely used but also because the variation in altitude and hence climate produces a range of exposures. At the higher elevations, fires for space heating burn for many hours in addition to the cooking fires; the houses are also more tightly built to conserve heat. In the Terai and lower elevations, there is no need for heating and houses are better ventilated. Natural controls for exposure are thus easily available. A series of studies that take advantage of these variations are being conducted.

A survey of two villages outside Kathmandu revealed a prevalence rate of 18.3 percent for chronic bronchitis and rates of 3.1 percent and 1.5 percent for emphysema and cor pulmonale (Pandey, 1984a). Rates were higher among smokers and ex-smokers than non-smokers and rates were similar among men and women even though fewer of the latter were smokers (Pandey, 1984b). To test the hypothesis that the comparable prevalence among women was due to exposure to cookstove smoke, data were collected on the number of hours per day spent near the stove. A statistically significant relationship was found between prevalence of chronic bronchitis and hours spent near the stove (Pandey, 1984b).

In addition, Pandey et al. (1985b) measured lung function in smoking and non-smoking women of ages 30-44 years in various exposure categories and found a significant positive correlation between deterioration of lung function and domestic smoke exposure. The declining trends in lung function were significant among smoking women but not among non-smoking women which suggests a possible synergistic effect.

Finally, a study of the incidence of ARI among 1000 infants and children of 0-5 years is being carried out in a rural area of the Hill Region of Nepal. Once again, incidence is being related to hours spent near the stove and preliminary data show a statistically significant association between moderate and severe cases of ARI in 0-2 year olds and this measure of exposure (Pandey et al., 1985a; Pandey, 1985).

Southeast Asia: Among many of the southern Chinese living in Southeast Asian countries such as Malaysia as well as Taiwan, China, and Hong Kong, there has been noted a high incidence of nasopharyngeal cancer (NPC) (Armstrong, 1978; Smith, 1987b). Many of these studies have suggested and later discounted unvented cookstoves as a risk factor for NPC. The consensus appears to be that exposure to woodstove smoke is a subsidiary factor at most in the aetiology of NPC. Recent evidence indicates that salted fish in the diet may be related to excess NPC (Yu et al., 1985). These findings are relevant in considering the study of NPC incidence in Kenya which is described briefly in the following pages.

People's Republic of China: Extremely high lung cancer rates were found in the mid-1970s in Xuan Wei county, even among women though less than one percent of them smoked. Since these high rates could not be accounted for by cigarette smoking or occupational exposures, He et al. (1986) concluded that domestic use of smoky coal was the probable cause. Mumford et al. (1987) later reported a statistically significant association between lung cancer rates and smoky coal use in Xuan Wei.

Papua New Guinea: Since the 1960s when a high prevalence of chronic bronchitis was documented in the highlands of Papua New Guinea (PNG) (Woolcock and Blackburn, 1967; Cleary and Blackburn, 1968), several studies have been undertaken to investigate the aetiology of the disease and have examined exposure to domestic wood smoke as a possible risk factor. Unfortunately, 20 years later, there are no definitive conclusions.

Woolcock et al. (1970) reported that chronic lung disease is common in the PNG highlands but that it was somewhat different in nature from that found in Europe. Prevalence was equal among men and women suggesting a common chronic irritant such as wood smoke. The nature of the disease was different as well. Specifically, more fibrosis was found in PNG, a condition that Woolcock et al. linked to woodsmoke exposure.

Master (1974) examined 94 people of different ages for chronic lung disease and found a high prevalence of pulmonary abnormalities in both sexes and at all ages. He concluded that a multiplicity of factors were probably responsible for the high rates but that "air pollutants from smoky fires in poorly ventilated huts remain the major and most preventable factor" (Master, 1974).

Cooke and Toogood (1975) report on a pathological study of 47 lungs obtained at post mortem. They found several cases where the patient had had chronic lung disease but there were no carbon deposits in the lung; on the other hand, they found emphysema cases with significant carbon deposits. They detected no difference in carbon deposits between highland and lowland patients and the degree of carbon pigmentation of the lungs did not appear to be significantly more than that found in autopsies in London. Cooke and Toogood (1975) decided that repeated respiratory infections were a major factor in the aetiology of chronic lung disease in PNG and that exposure to domestic wood smoke was of secondary importance.

Anderson (1978) compared respiratory abnormalities and ventilatory capacities among coastal and highland school children who had different exposures to domestic wood smoke. He found no significant differences up to the age of ten. Later, Anderson (1979a) studied a population of almost 1300 in the PNG highlands and reported that lung function decreased from middle age among both males and females. He also found that these decreases and chronic respiratory symptoms were not associated with tobacco smoking. He writes:

> The question of wood smoke pollution may be clarified in the future by epidemiological studies of townspeople living in pollution-free houses. At present, however, it appears reasonable to conclude that since the principal chronic lung disease is known in other contexts to be caused by a variety of inhaled substances, and since there is good evidence on which to exclude tobacco smoking, wood smoke pollution must remain a major aetiological possibility.

Research on these issues continues. A recent survey of the prevalence of chronic nonspecific lung disease in the Eastern Highlands of PNG found comparable prevalence between men and women, increased prevalence with age, but a significant excess prevalence only in the over-60 year age group (Smith, 1987b). Personal monitoring of exposure to air pollutants and the keeping of activity logs might help resolve this ongoing debate. Obviously, there are some vital pieces of information that epidemiological research has not revealed so far. A better understanding of the spatial and temporal variations in air pollution is probably required.

<u>Africa:</u> Some of the earliest air pollution monitoring studies come from Kenya where an elevated incidence of NPC was studied (Clifford, 1967). Hoffmann and Wynder (1972) and Clifford (1972) found the concentration of polycyclic aromatic hydrocarbons (PAH) in village huts was correlated with elevation and that the incidence of NPC was correlated with elevation as well. The relationship between NPC and exposure to PAHs remained unclear, however, and it was suggested that perhaps other factors such as soil and water which are also related to elevation were influential in determining NPC rates (Clifford, 1972).

More recently, Kossove (1982) compared respiratory symptoms among Zulu infants exposed to smoke from cookfires for different lengths of time. He divided the group into "exposed" and "non-exposed". Exposure was determined by oral survey and the "exposed" group had an average exposure period of 7.4 hours while the period for the "non-exposed" group was 6 hours which is not a statistically significant difference. He found 70 percent of those with respiratory symptoms had been exposed in comparison with 33 percent of those without symptoms. In weighing the evidence, Kossove (1982) noted that poor ventilation combined with crowded living conditions may lead to an increase in the bacterial and viral airborne pathogens. Further, "there is a probably synergistic effect of the smoke irritant on host vulnerability to respiratory pathogens." An earlier study in Nigeria (Sofuluwe, 1968) arrived at a similar conclusion.

The results of these studies are confusing. No clear picture of health effects emerges. This is particularly true of the research in PNG; that is discouraging since the issue has been studied there longest and in the most systematic manner. Perhaps what is needed is simultaneous measurement of exposure and health impact within the framework of an intervention study where reductions in exposure and short-term health impacts would be discernable. These are, however, efforts beyond the purview of this dissertation. For the purposes here, it is assumed that daily exposure to such high levels of pollution could not possibly be conducive to human health and welfare.

Study Site Selection and Organization of the Dissertation

The search for field sites was guided by two main criteria: that the village should have both old (traditional) and new (improved) stoves in sufficient numbers to allow a comparison of performance; that one village should be in a Hindi-speaking area of north India, and the other in a Kannada-speaking area of south India. The second criterion allows a comparison to be made between two places that are strikingly different especially in terms of diet and cooking practices.

Keeping the first criterion in mind, I started visiting villages identified with the help of various improved stove dissemination organizations. These were usually non-governmental organizations involved in several rural development projects, of which the stove program was only one. My main contact in the north was the All India Women's Conference (AIWC), and in the south, the Centre for the Application of Science and Technology to Rural Areas (ASTRA). The major difficulty proved to be in finding a village with more than a handful of operating improved stoves.

Eventually, Garhibazidpur, Haryana, and Keelara and Pallerayanhalli, Karnataka were selected because:

* their locations offer a good geographical contrast. A major part of understanding the patterns of domestic air pollution, once they have been described, consists of delineating the influences of culture and environment. This dissertation attempts to illuminate these relationships by comparing two vastly different geographic areas.

* they have been participants in improved cookstove programs in the recent past and thus allow a useful comparison to be made between the traditional stove and the new stove. The effectiveness of the most commonly proposed solution to domestic air pollution is examined in two very different settings.

* although not remote by any means, they are still largely agricultural villages and hence fairly representative of Indian villages in general.

* they are relatively accessible, an important characteristic, considering the type of air pollution monitoring equipment in use.

* the spoken languages were Hindi and Kannada, both familiar to me, which made the survey portion of the study easier and more effective.

The original intention was to focus on one village each in the north and the south. However, due to logistical problems in the south during the monsoon monitoring session, some measurements had to be taken in Pallerayanahalli, a village that is more accessible than Keelara. These Pallerayanahalli households were monitored again during the "summer" monitoring session and surveyed along with the Keelara households. Pallerayanahalli is a village of lower-caste, itinerant peddlers who have recently established permanent residences. Though social differences exist between Keelara and Pallerayanahalli, the stoves and kitchens are much the same.

The variables of interest in all three villages were kitchen location and construction material, type of stove, type of fuel, cooking practices, diet, and ambient air pollution levels. Each of these affects exposures in some way. Though the available information is inadequate to precisely quantify these influences, the general direction of the effect can be surmised. Table 7 summarizes the characteristics of the specific environment within which exposure occurs in these villages as well as indicates their probable effect on TSP exposures. During fieldwork, data were gathered to verify these assumptions.

Field testing of improved cookstoves for effectiveness in reducing domestic air pollution has not been a standard component of dissemination programs though many have conducted limited field testing for improved efficiency. Therefore, the few field data available (Smith et al., 1983; Reid et al., 1986) were collected in pilot research projects. Laboratory testing for emissions reductions has also been done only recently (Jindal and Prasad, 1987) and there are not many examples of simulated field testing (Smith et al., 1984; Joseph et al., 1985; Ahuja et al., 1987). The evidence is by no means conclusive. Field performances usually do not match laboratory performances and are sometimes lower to the point of being comparable to those of traditional cookstoves. The performance of improved and traditional cookstoves also vary substantially from operator to operator, from place to place, and over time. Demonstrated improvement under controlled conditions does not guarantee similar success in the field. Independent of technical considerations of stove design, the dissemination strategy employed is critical to the acceptance of improved cookstoves. Keeping these considerations in mind, the effectiveness of the improved cookstoves in reducing domestic air pollution was examined in each of the study areas.

The effect of fuel type was also studied; this has not been done systematically in field situations but existing information would lead to the hypotheses that exposures would be greatest in households using dung, intermediate where crop residues are burned, and lowest where wood is the cooking fuel (INIOH, 1980). To test these assumptions, fuel type was noted during each air pollution monitoring session and later included as a variable in the analysis of variance.

The effect of different kitchen locations and construction materials has not been studied earlier either though the effects of differences in ventilation conditions has been investigated (Smith, 1987b). It was expected that an outdoor

Table 7. Expected Effect of Various Environmental and Cultural Factors on TSP Exposures

Factor	Garhibazidpur	Keelara/Pallerayanahalli
Kitchen	Indoor, protected, outdoor; seasonal changes in location (D)	Indoor and enclosed; location fixed (I)
Stove	Old--U-shaped clay stove, fixed and portable, single port (I) New--high-mass fixed clay stove, two ports, front and chimney dampers, flue (D)	Old--high-mass fixed clay stove, three ports (I) New--high-mass fixed clay stove, three ports, flue and enclosed fuel box (D) Old with hood--high-mass fixed clay stove, two or three ports, set under a hood-like chimney (D)
Cooking fuel	Acacia nilotica, wastes from mustard, sesame, and other crops, dung (I)	Coconut wastes, assorted fuelwood, dung in the summer (I)
Cooking process and diet	Rotis are mainstay of diet, close supervision of cook required (I)	Rice and ragi staples, cook's presence near stove not required (D)

(Increase) or (Decrease) = Expected direction of effect on exposure.

kitchen or one constructed from thatch or some similar permeable material would argue for lower exposures than would an indoor or enclosed kitchen in a mud-and-stone house.

Another parameter that has not been examined previously is diet and, in relation to that, cooking practices. Cooking processes that require the constant or close attention of the cook might be expected to lead to higher exposures. This is a basic north-south cultural distinction, so one would expect exposures to be somewhat higher in Garhibazidpur and slightly lower in Keelara and Pallerayanahalli.

Finally, if ambient or background TSP levels are high, TSP exposures may also increase though the location of the stove also has a bearing on this. There is evidence that ambient TSP levels are, in general, likely to be higher in north India than in south India (Smith and Durgaprasad, 1987). This would have the effect of increasing exposures slightly in Garhibazidpur.

This is a simplistic, linear view of how these factors affect exposures. Beyond these direct relationships there are many other possible interactions which are not easy to identify and very difficult to quantify. Perhaps with more elaborate instrumentation, a larger research team, and a longer time period in each study site this could be achieved. For the present, only the direct relationships are considered and a crude system of weighting is attempted.

The extent to which these expectations or speculations on the nature of these relationships are actually met in this particular set of data is discussed in Chapter 4. A more detailed description of all three villages, Garhibazidpur, Keelara, and Pallerayanahalli is given in the next chapter. The methodology is described in Chapter 3 which also discusses the assumptions made, and the merits and disadvantages of specific data collection techniques. Chapter 4 presents the analysis of data and results of the air pollution monitoring as well as the field survey of opinions regarding fuel use, stove performance, and air pollution. The implications of these findings for improved cookstove dissemination programs are discussed in Chapter 5 and the results placed in the context of the dissemination strategies employed in the study areas. Finally, the concluding chapter draws together the various elements of the dissertation, summarizes the findings, and suggests directions for future action.

Chapter 2

PLACE

The General Environment: Place and People

Garhibazidpur is in Haryana, about 50 km southwest of Delhi (Figure 2). The terrain around the village is flat; the only topographical feature of interest is the Aravalli range which is visible in the mid-distance. The hills here are, in the words of Spate and Learmonth (1967), "little echelonned ridges, half-buried in the Indo-Gangetic alluvium" and covered by sparse scrub. Spate and Learmonth (1967) quote Aldous Huxley in conveying the general ambience of the area:

> Once in every ten or twenty yards, some gray-green plant, deep-rooted, and too thorny for even camels to eat, tenaciously and with a kind of desperate vegetable ferocity struggles for life. And at longer intervals, draining the moisture of a rood of land, there rise, here and there, the little stunted trees of the desert. From close at hand the sparseness of their distantly scattered growth is manifest. But seen in depth down the long perspective of receding distance, they seem -- like the in fact remotely scattered stars of the Milky Way -- numerous and densely packed. Close at hand the desert is only rarely flecked by shade; but the further distances seem closed with a dense dark growth of trees. The foreground is always desert, but on every horizon there is the semblance of shadowy forests (Huxley, 1927).

This admirable passage was written of Rajasthan, but it applies to much of the Indus Plains (and of Australia), and, with larger trees and a less dead foreground, to vast areas of those of the Ganga and the Peninsula.

Average annual rainfall is 35-40 cm; most of this precipitation occurs in June-August though there are brief winter showers. Peak temperatures occur in May (42-45°C). Winters are known for their low night and early morning temperatures (8-10°C) and atmospheric inversions. Water for drinking and irrigation, is a problem in Haryana as the water table is low and wellwater when available is often brackish. "Nevertheless," observe Spate and Learmonth (1967), "the sandy loams are remarkably drought resistant and crop failure is less frequent than might be expected considering the low rainfall." The principal crops in Garhibazidpur are wheat, mustard, barley, and sesame. Less important crops are grams (leguminous plants such as the chickpea that are grown for their seeds), sugarcane, and sorghum.

Garhibazidpur has 285 families; most of these are involved in agricultural activities. The urban influence is readily apparent, however, and will probably grow in the future. Several families have one member who works in a "city" job,

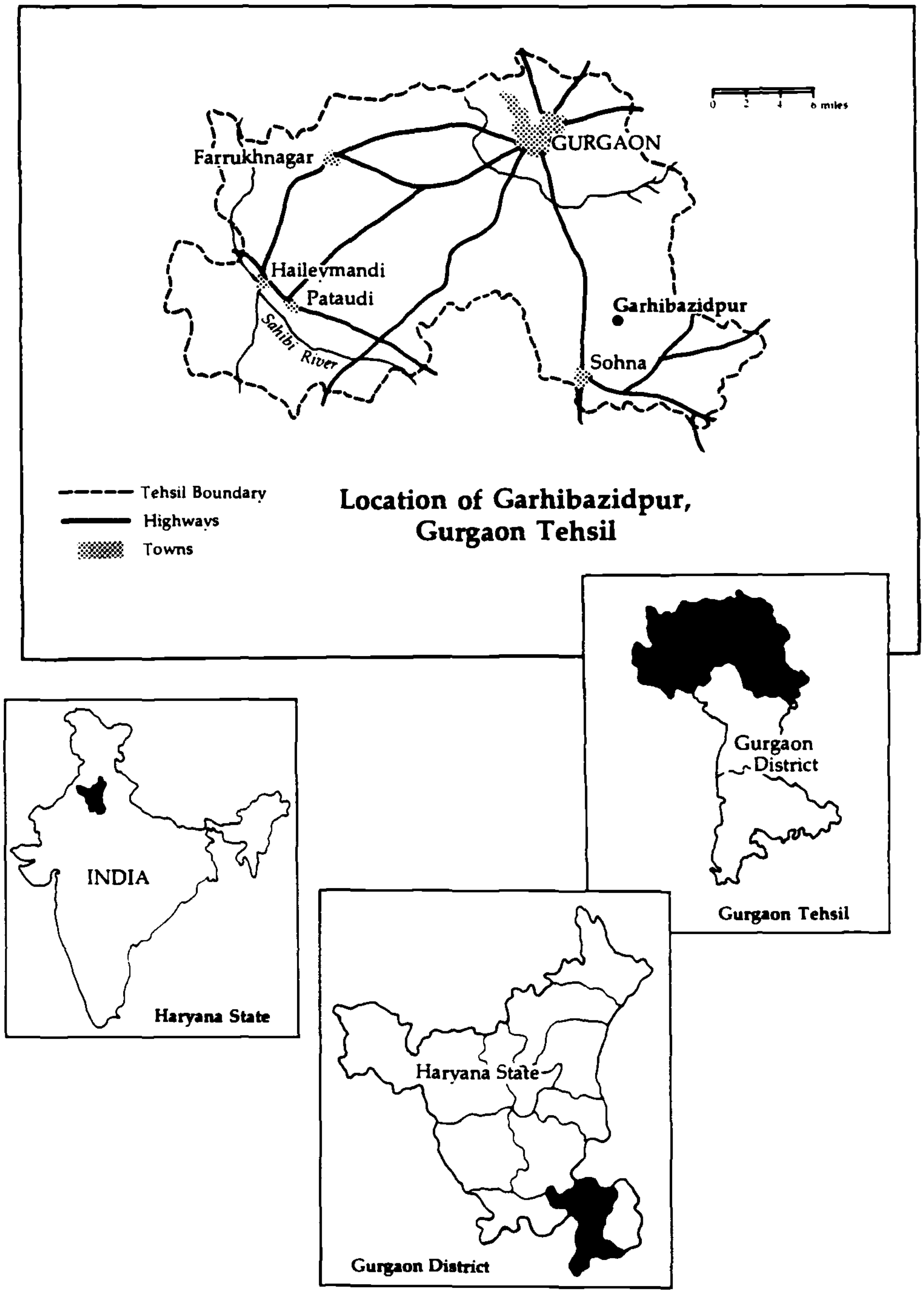


Figure 2. Location of Garhibazidpur

that is, travels to Gurgaon (district headquarters) or Delhi everyday and is employed as a clerk, driver, factory worker, or policeman. Ahirs make up the largest caste group in the village; there is also a fairly large Harijan community as well as some Muslim families. Many of the Harijan households have family members in the Border Security Force or the armed forces. The average family size in Garhibazidpur is 6.8. There are several joint families but the trend seems to be towards divided households and nuclear families. Further, though a joint family may occupy one house or live around one courtyard, it is unusual for them to share one hearth.

Village lore has it that Garhibazidpur was originally one of Aurangzeb's garrisons. The walls of the old fortification still stand and many of the houses incorporate the stone blocks in their structure. There is a variety of housing styles ranging from simple one-room thatch-roofed dwellings to elaborate "haveli" style houses which have central courtyards encircled by rooms.

The fields surround the houses which cluster together. The village is about 4 km from the highway that connects Gurgaon and Sohna (block headquarters). The road leading to the village was recently paved and there is a bus service between Garhibazidpur and Gurgaon twice a day. The nearest town, Sohna, is 11 km away. The village is connected to the electricity grid but supply is extremely erratic and unpredictable. In addition, several households (particularly the thatch-roofed homes) do not have connections. Wells and handpumps provide the water supply. Wells within the village itself yield brackish water which is not used for drinking. Hence, drinking water is normally carried in from handpumps on the outskirts of the village. Irrigation water is scarce, as there are no canals and rainfall is uncertain and generally low. Many households have irrigation pumps but their use is constrained by the sporadic electricity supply.

Garhibazidpur has a primary and middle school. There is a rural health center 6 km away. When the center is adequately staffed, a doctor and a nurse conduct clinics in the village once a week. There are three small shops in the village which operate on a cash, credit, and barter system and supply the whole spectrum of incidental needs. For major supplies, most people travel either to Sohna (also the location of the nearest kerosene shop) or to Gurgaon.

Keelara and Pallerayanahalli are in southern Karnataka, Tumkur district, north of Mysore and about 115 km west of Bangalore (Figure 3). Spate and Learmonth (1967) quote the following description of the plateau or "Maidan" that makes up much of peninsular Karnataka from the Mysore Gazette (1908):

> The Maidan consists in general of rolling plateaus rising in the east (between Tumkur and Kolar) into disjointed granitic hills of fantastically irregular plan and elevation. But there is a great deal of local diversity. 'The level plains, of blackish soil, in the north, are covered with plantations of sugar-cane and fields of rice; those irrigated by tanks have groves of coconut and areca palm; the high-lying tracts of red soil, in the east, yield ragi and other 'dry' crops; the stony and widespreading pasture grounds, in the central part of the country, are stretches of coarse grass, relieved by shady groves of trees', among which acacia and wild dates are prominent.

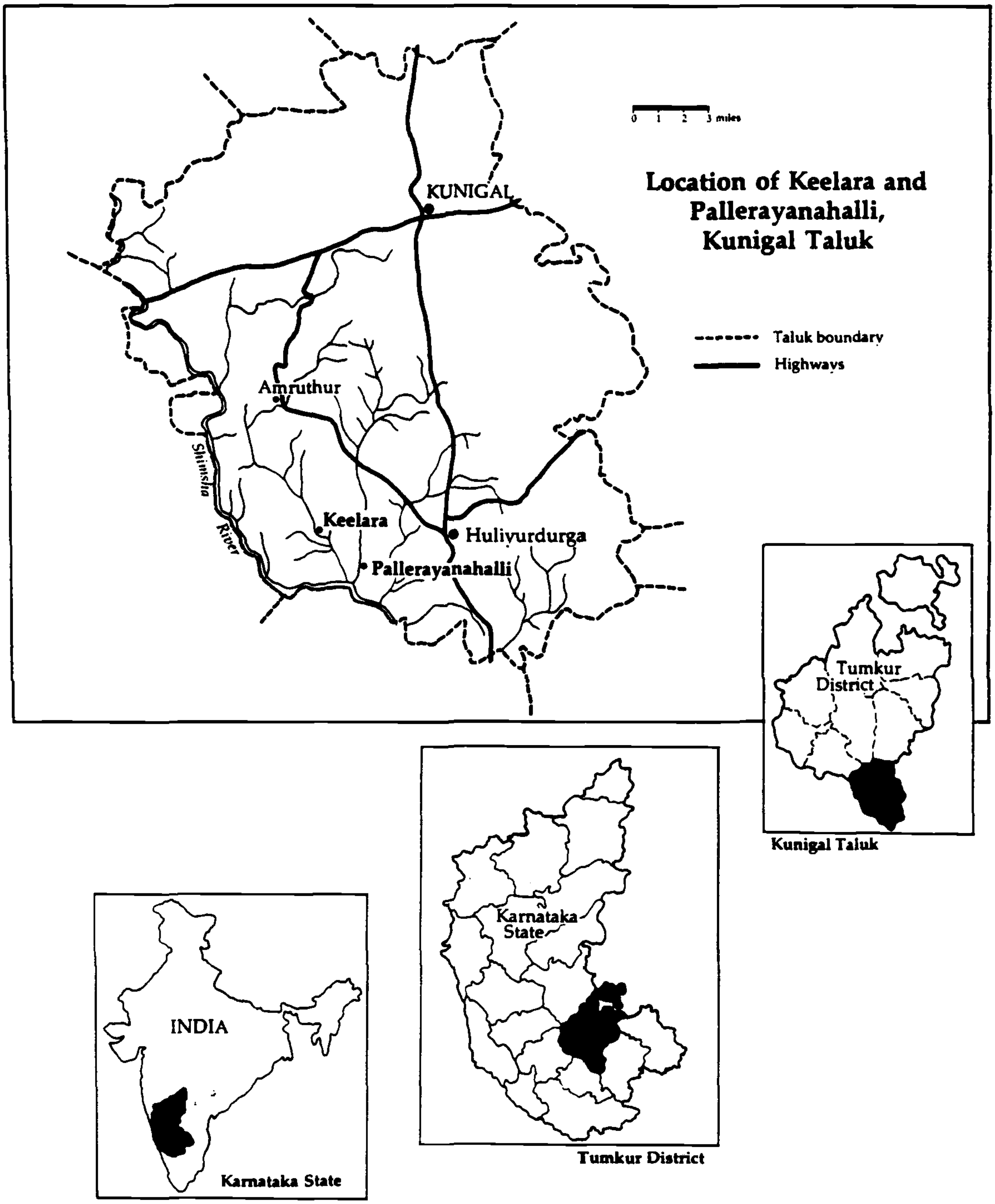


Figure 3. Location of Keelara and Pallerayanahalli

Like southeastern Haryana, this is a semi-arid area; average annual rainfall is 75 cm. There are two peaks in rainfall, one occurring in May, and the other in September. In November, there is a sharp decrease in precipitation and December through April are relatively dry months. Peak temperatures (35-38°C) occur in February, March, and April. Cooler temperatures normally accompany the rains. This part of Karnataka is prone to drought. Dry land harvests are often meagre or even absent due to lack of water. Keelara has had a below-average harvest since 1984. As Keelara is at the end of a network of irrigation canals from Marconahalli Dam, this source of supply is irregular depending on the amount of rainfall upstream and the magnitude of the surplus generated.

The soil can be characterized as sandy clay loam with pockets of black clay. The dry land crop regime is only interrupted where tank or canal irrigation is available. In these spots, coconut groves, paddy, high yielding varieties of ragi (Eleusine coracana), and sugarcane can be seen. The principal crops grown are ragi and paddy. Subsidiary crops include sugarcane, pigeonpea, castor seed, and horsegram.

Keelara has 200 families most of whom, like Garhibazidpur residents, are involved in agricultural activities. There is no commuting work force here as there is in Garhibazidpur as the distances are too great. Many of the younger people, however, go to Bangalore in search of employment after completing high school and remain there as factory workers. The majority of the people are Vokkaligas; there is also a fairly large scheduled caste and tribal population. The average family size is 6.5.

Like Garhibazidpur, Keelara has a nucleated settlement pattern. The older houses in the center of the village are of stone and mud and are very poorly ventilated. Narrow alleys separate clusters of houses. Houses often have common walls, hence sometimes the only inlet for light and air is the front entrance. These are generally one-room dwellings with low walls which separate the living area from the kitchen and the livestock pen. The kitchen is at the rear of the house, with small skylights for ventilation. Even in this older part of the village, the wealthier landowners have spacious courtyards where their animals are stabled. Thatch and mud dwellings are fairly common; these houses also lack windows but the thatch provides egress for smoke from cooking stoves. Some of the mud-and-stone houses are now unoccupied and thatch houses are becoming less common as the central government's low-cost housing scheme gathers momentum. These new houses are constructed at the fringes of the village and are usually high-roofed, single-room buildings with a low wall to partition the kitchen from the living area. The stove is generally north-facing in accordance with tradition. Windows in opposite walls provide cross ventilation. In contrast to the older homes, these are well lit and airy. The improved cookstove is not always a part of the package but people often choose to have improved cookstoves built in the new house under the subsidy program.

Keelara straddles a road that links Tumkur and Mandya (both district headquarters). There is a bus service between Keelara and Bangalore four times a day. The nearest town is Huliyurdurga, at a distance of about 15 km. Some facilities (post office, health center, and so on) are available at Yedavani, a smaller town, only about 5 km away. The village is connected to the electricity grid; supply is more reliable here than in Garhibazidpur. There are still many homes without connections. As in Garhibazidpur, wells and handpumps provide drinking water supply. The Keelara tank supplies water for washing and other domestic needs, as well as for irrigation.

Keelara has a primary and middle school. There are several small shops in the village as well as a cooperative store where subsidized rations and kerosene are available. For other supplies, people normally go to Huliyurdurga.

Pallerayanahalli is roughly 6 km from Keelara. It has about 60 families, most of whom are peddlers who still walk the circuit but now return frequently to their residences in Pallerayanahalli. Many own land but these are invariably dry lands so the harvest yields are always uncertain. None of them are full-time farmers. Many are weavers, some are in sericulture, some are bonded labor, and many of the young men work as farmhands at the Indian Institute of Science's (IISc) extension center which is less than a kilometer away. Many of the women make day trips to neighboring villages on a regular basis, often walking ten miles a day, to peddle buttons, thread, bangles and other small items. Most of the homes are new brick-and-tile constructions, built under the auspices of the government's low-cost housing scheme.

The Specific Environment: Kitchen, Stove, Fuel, Diet, and Cooking Practices

There are, then, some similarities but many more disparities in place and people between the villages being studied. One similarity that might be mentioned is that both Garhibazidpur and Keelara are villages in transition. Though they retain their agricultural base, this is being eroded slowly by the migration of young men to the city and by the fragmentation of joint family landholdings. This process is more evident in Garhibazidpur probably because it is closer to an urban center and because Haryana is more affluent than Karnataka. These are environments and societies in change, and the preceding description presents a snapshot view.

This general description of the villages gives the broader context within which indoor air pollution occurs and was studied. A more detailed examination of the specific environment within which exposures actually occur is needed. "Specific environment" here refers to the structure and location of the kitchen, stove(s) used, cooking fuel(s) burned, cooking practices followed, and the diet of the people.

The relation of stove and fuel to indoor air pollution is quite obvious. Kitchen location and structure are of interest mainly because of its impact on ventilation in the cooking area. Diet influences cooking practices and processes. These in turn determine to a large extent the exposure of the cook. How close is she to the stove? How long does she stay near the stove?

Another important task is to identify the population at risk. The questions here are "Who cooks?" and "Is anyone else present while the cook is at the stove?" Within the hierarchy of the household, the task of cooking usually falls to the most recently-married daughter-in-law who may or may not be the wife of the eldest son. In her absence, the cook is the daughter of the house if she is old enough, or, by further default, the senior female household member who may be the wife or the mother of the household head. The second question of who else is present in the kitchen while the stove is being operated was difficult to answer because our presence often caused a great influx of visitors to the kitchen. Based on conversations with cooks though it would seem that, in general, infants and young children stay by their mothers especially during the colder winter months.

<u>Garhibazidpur:</u> In Garhibazidpur, only the more affluent have formal kitchens. It is more likely that the stove is in the courtyard and is protected by a thatch roof and perhaps one or two low walls. The location of the kitchen can be broadly categorized as indoors, in a protected but not completely enclosed space, or outdoors. The location of the stove may change many times in the course of a year and sometimes even in the course of a day. The climatic variations experienced are responsible for this. Winter mornings can be bitterly cold whereas the afternoons are pleasant and the evenings chilly. Summer afternoons, on the other hand, are usually unbearably hot. Some stoves are portable; others are broken and rebuilt in different locations with no significant change in design.

A survey of 62 Garhibazidpur households (sample selection and survey procedure described in Chapter 3) showed that in the winter about 30 percent cook indoors, a slightly smaller percentage cook in a protected area, and a still smaller percentage cook outdoors (Table 8). About 13 percent keep both an indoor and an outdoor kitchen operational and alternate between the two depending on immediate conditions. In the summer, about 35 percent maintain an outdoor kitchen, about 30 percent a protected one, and approximately 22 percent maintain both indoor and outdoor kitchens. In the monsoon there is a wholesale move back to indoor kitchens (50 percent), 24 percent continue to have protected kitchens, and almost 20 percent keep both indoor and outdoor kitchens. The number with only outdoor kitchens is negligible in this season. As might be expected, the major movement is between indoor and outdoor kitchens. The percentage of households using protected kitchens remains fairly constant.

The traditional or old stove is a U-shaped clay stove. The fire is built inside the "U" which acts both as a fire shield and as a support for the cooking pot. Fixed and portable versions of this stove are found in most households. The fixed U-shaped stove is ubiquitous; in fact, some households have two or three--one in the indoor kitchen, one in the outdoor, and so on (Table 9). The portable U-shaped stove is less widespread, but still more common than any other stove type in the village. The second most commonly found stove in Garhibazidpur is the newly introduced improved chula (Hindi term for 'stove') which is a high-mass fixed clay stove with a chimney. This stove is equipped with front and chimney dampers and the provision of two ports allows two dishes to be prepared simultaneously (Figure 4). The kerosene stove is almost as commonly found as the new chula. This is rarely used for meal preparation but many households keep it for emergency use and for making tea. There are a few gas and electric stoves in the village but the numbers are negligible and in no case are they the primary means for cooking. Besides the traditional stove, most households also have a 'hara'. The hara is a large bowl-like receptacle or hollow in the ground which is lined with pieces of dried dung; these dung pieces once ignited smoulder for

Table 8. Kitchen Location by Season in Garhibazidpur

Location	Winter n	Winter %	Summer n	Summer %	Monsoon n	Monsoon %
Indoor	19	31	5	8	31	50
Protected[a]	17	27	18	29	15	24
Outdoor	16	26	22	35	1	2
Protected and Outdoor	2	3	3	5	1	2
Indoor and Outdoor	8	13	14	23	12	19
Indoor and Protected	-	-	-	-	1	2

[a] A protected kitchen is one that is at least partially exposed to the elements. Usually, these had roofs and two or three walls.

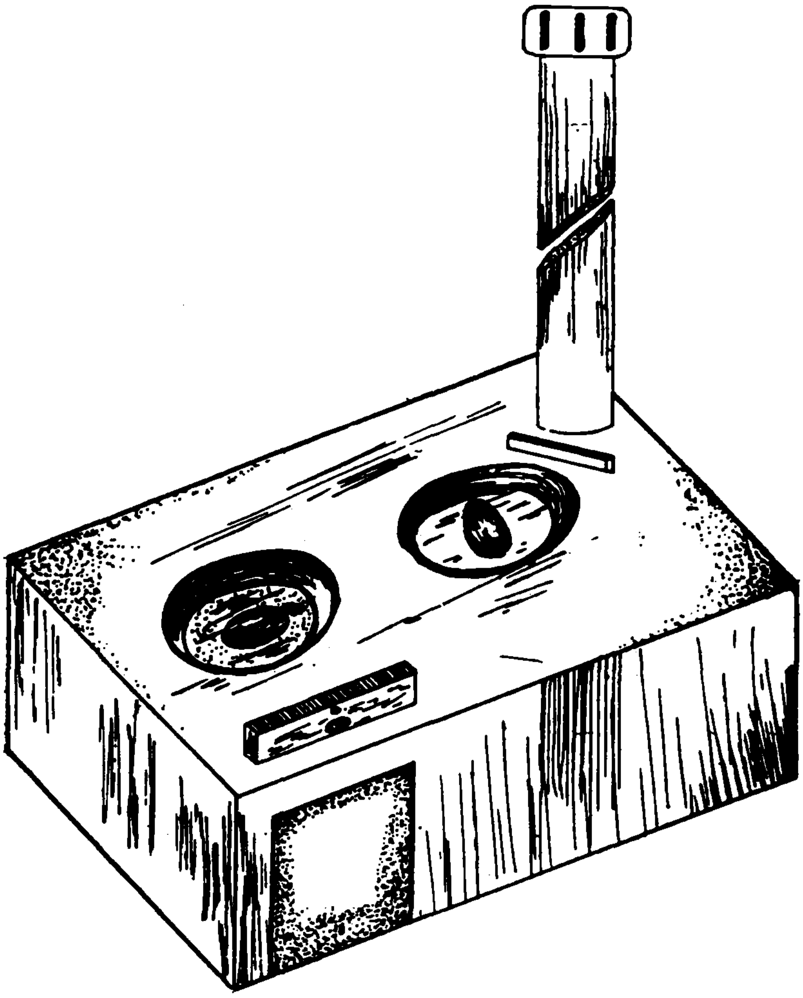
Table 9. Stove Type by Season in Garhibazidpur

Stove type	Winter[a] n	Winter[a] %	Summer n	Summer %	Monsoon n	Monsoon %
Fixed U-shaped	48	77	48	77	30	48
Portable U-shaped	3	5	8	13	21	34
One port w/chimney	-	-	2	3	3	5
Sahayog	14	23	12	19	15	24
Kerosene	3	5	2	3	11	18
Electric	-	-	-	-	1	2
Gas	1	2	-	-	1	2
Three-brick	1	2	-	-	1	2

[a] Column percentage totals do not add up to 100 because some households were using more than one stove type regularly. Total n = 62.

hours. This device is used for simmering milk and for slow cooking. The survey showed that 60 percent of the households have both fixed and portable haras and only about 10 percent have neither. The prominence of this particular cooking device is quite understandable given the importance of milk and milk products in the diet.

In the course of the survey, cooks were also asked which stove they considered their "all-purpose" stove, that is, on which stove they did most of their cooking (Table 10). Most people answered the fixed U-shaped stove (74 percent). A little over 10 percent said the new chula. The portable U-shaped chula and a modified form of the new chula accounted for another 10 percent.



Note: Taken from advertising material produced by Swarajya Bharati.

Figure 4. The Sahayog chula

Table 10

Stove Use by Purpose or Task in Garhibazidpur

Stove type	All purpose n[a]	%	Roti making n	%	Large numbers n	%	Coffee/ tea n	%	Bad weather n	%	Good weather n	%	When in hurry n	%	Abandoned n	%
Fixed U-shaped	46	74	2	3	-	-	-	-	3	5	9	14	2	2	-	-
Portable U-shaped	4	6	-	-	-	-	-	-	16	26	5	8	-	-	-	-
Two port	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
One port w/chimney	3	5	-	-	-	-	-	-	1	2	-	-	-	-	1	2
Sahayog	8	13	-	-	1	2	-	-	5	8	1	2	-	-	6	10
Kerosene	1	2	-	-	1	2	10	16	8	13	-	-	2	3	2	3
Electric	-	-	-	-	-	-	2	3	1	2	-	-	1	2	-	-
Gas	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-
Three brick	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-

[a]Total n = 62.

Residues from the sarson (mustard) and til (sesame) crops are important cooking fuels in Garhibazidpur. Keekar (Acacia nilotica) is the other major fuel. Cut logs are rarely used as cooking fuel. The keekar is generally in the form of thorny twigs. Dung is also burned in the cooking stove but generally in combination with crop residues or keekar. It is burned by itself only occasionally to prepare dishes that require slow cooking. Seldom is a single cooking fuel used. A combination of two or three different types of fuel is the norm. Keekar with dung, and keekar with some type of crop residue are the most common combinations.

There are seasonal changes in fuel use. In the winter, the survey showed, 74 percent of the households use keekar. A much smaller number of households (about 20 percent) use dung and guar (Cymopsis tetragonoloba) (Table 11). In the summer, the first position is taken over by sarson (70 percent), supplemented by keekar (50 percent) and dung (28 percent). The gap between sarson and keekar is reduced in the monsoon (58 and 56 percent) and the number of households using dung decreases (13 percent). Different crop residues are prominent in different seasons. In winter, guar and til are most commonly used. Sarson, which is a winter crop and is harvested later, is used mainly in the summer and monsoon.

Generally, people obtain cooking fuels from their own lands or gather them from roadsides; only a few families buy cooking fuel. The survey showed that 56 percent of the households gather fuelwood (Table 12). A further 30 percent collect it from the borders of their fields and from their own property. Only about five percent of the households buy fuelwood. Another four percent buy as

Table 11. Cooking Fuel Use by Season in Garhibazidpur

Cooking Fuel	Winter		Summer		Monsoon	
	n	%[a]	n	%	n	%
Keekar[b]	46	74	32	51	35	56
Dung	13	21	9	28	8	13
Guar	12	19	-	-	-	-
Sarson	10	16	44	71	36	58
Til	9	14	-	-	-	-
Crop residues	-	-	3	5	2	3
Kerosene/electricity	-	-	-	-	3	5
Dhaincha	-	-	-	-	2	3

[a] Column percentage totals do not add up to 100 since most households use more than one type of fuel in each season.
[b] Keekar = Acacia nilotica; guar = Cymopsis tetragonoloba; sarson = mustard; til = sesame; daincha = Sesbania bispinosa.

Table 12. Means of Procuring Cooking Fuel in Garhibazidpur

Source	Fuelwood n	Fuelwood %	Crop residues n	Crop residues %
Own	19	31	40	64
Buy	3	5	-	-
Gather	35	56	2	3
Buy and gather	2	3	-	-
Own and gather	3	5	-	-
Given (gratis)	-	-	12	19
Given (service)	-	-	4	6
Not applicable	-	-	4	6

well as gather fuelwood. Almost all of the fuelwood gathered in this manner is keekar. There are a few khathis or carpenters in the village who sell wood, basically remnants from their trade. The species commonly so sold include neem (Azadirachta indica) and banyan (Ficus bengalensis).

The average distance travelled for fuelwood collection is 4 km (one way). Most households find time during slack agricultural work periods to gather fuelwood on several consecutive days, and build a stockpile that will last for a few weeks. Some families collect fuelwood everyday in the winter when the weather is more favorable to these expeditions. Only a few make the trip on a daily or near-daily basis. In most households, the cook herself or other female household members are responsible for gathering the cooking fuel.

People, for the most part, collect crop residues from their own fields. There are, however, arrangements made whereby landless families are able to obtain residues. Usually this involves an exchange of labor for a fraction of the residues from the harvest.

The diet consists almost invariably of roti (unleavened bread) and subzi (vegetable dish), regardless of economic class. The quantity consumed varies, of course. One-pot hara meals may be prepared in the summer and sometimes in the monsoon. This usually consists of grain and milk cooked slowly along with brown sugar. The type of vegetable changes over the year and milk, yogurt, lassi (diluted yogurt), and ghee (clarified butter) are important components of the meal particularly in the summer. The cooking process, however, remains more or less the same all year round.

The roti-making process requires that the cook sit by the stove the entire cooking period. The dough is rolled out in roughly circular forms and put on a tava or metal griddle. After a minute or two on the tava, the roti is removed and propped against the inside wall of the combustion chamber, close to the radiant flame. The hot air causes the roti to puff up; the cook rotates it occasionally while keeping an eye on the roti on the tava and patting out a new roti. The roti-making process in the average family takes anywhere from twenty minutes to half an hour. The usual procedure is for the cook to prepare the subzi first. While this cooks slowly on a dung fire, the cook kneads the dough for the rotis. By the time the first rotis are cooked, the family is often gathered and ready to eat.

Today, the rotis are made from wheat flour. Twenty years ago it was customary to eat bajra (bulrush millet) rotis in the winter months. Bajra is harvested in August or September, whereas wheat is ready for harvest in late March or early April. Bajra rotis are considered heartier and are a "hot" food, hence good to eat in the winter. They are, however, heavier than wheat rotis and take much longer to cook. Most of the younger generation eat wheat rotis all year round.

The custom of feeding agricultural labor during harvest and sowing seems to have become less common as well. Most people have adopted the time-saving option of paying their workers extra money instead of providing them with meals. Hence, the cooking schedule does not change radically with the agricultural cycle. Meals may be cooked earlier or later in the day, and the noon cooking session may be omitted, but the quantity and type of food cooked remains the same. This is in contrast to the practice in the south, where the tradition of feeding agricultural labor is maintained.

The number of cooking periods per day varies over the year. Almost all households cook thrice a day in the summer. Similarly, the village norm in the winter is two cooking sessions a day. In the monsoon, however, there is more variation. Since some people have space constraints, the cooking schedule often varies depending on the weather on any given day. Hence, though many families continue to cook three times a day (64 percent), about 30 percent cook only twice a day.

<u>Keelara and Pallerayanahalli:</u> Unlike Garhibazidpur kitchens, the kitchens and stoves in Keelara and Pallerayanahalli are a fixed and permanent part of the household. People invariably cook indoors--except when cooking for large numbers or preparing non-vegetarian dishes. As mentioned earlier, the kitchen is usually at the very rear of the house and is quite closed off from the outside world. Even at midday, the kitchen is often dark and cool. Sitting by a stove built by the present cook's mother-in-law, say thirty years ago, surrounded by tall stacks of shiny, black storage pots, and cooking utensils that date from a similar period, it is easy to believe that, of all places, change comes most slowly to the rural kitchen.

The traditional stove either has two ports or three ports depending on the size and economic status of the family. It is a high-mass fixed clay stove. Usually, the combustion chamber or central "U" has connecting passages to two flanking ports. These ports have rounded pot rests so that they can accommodate cooking pots of various shapes and sizes. This also means, however, that the pots do not fit snugly into the ports and so much heat and smoke is released into the kitchen. Those with brick and mortar kitchens often have a hood-like chimney over the stove. As in Garhibazidpur, the stove is constructed at ground level so the cook squats when cooking. The newly introduced improved stove here is also a high-mass fixed clay stove (Figure 5). This ole (Kannada term for "stove") has three ports and a chimney. Its design is such that, theoretically, it can be operated as a closed system once the fire is established; there is very little heat lost to outside air. The three ports are in line, and an increasingly narrow passage leads from one to the next. The grate is between the first and second port. The chimney is located beyond the third port. The fuel inlet slopes downwards slightly towards the first port and grate, and is provided with a lid which can be shut once the fire is established. There is a small aperture which acts as a secondary air inlet above the grate. There is also a gap below the grate for the removal of ash; this is normally covered by a metal flap. The three ports are sized according to the most commonly used cooking pots in the house. There is, or should be, no gap between the side of the cooking pot and lip of the port. There is also a U-shaped stove which is similar to the one used for cooking in Garhibazidpur except here it is larger and sturdier and is used for heating bathwater, making castor oil, etc., rather than for cooking.

About half the households surveyed had the new ole (Table 13). About a quarter of the people had the traditional stove with three ports and another quarter had the same stove with the hood-like chimney above. Roughly 15 percent had the traditional stove with two ports and another 15 percent had kerosene stoves. As in Garhibazidpur, some households had more than one stove, therefore the total does not add up to one hundred.

Here, too, cooks were asked which stove they considered to be their "all-purpose" stove (Table 14). More than 40 percent answered the new ole. Twenty percent said they relied on the traditional stove with three ports, and slightly more said they depended on the same stove with the hood chimney. About 11 percent use the traditional stove with two ports. Though some households in the village have kerosene and electric stoves, these are not used for cooking usually. As is the practice in Garhibazidpur, the kerosene stove is used mainly in emergencies and to make coffee or tea.

The most important cooking fuel in Keelara and Pallerayanahalli, regardless of season, is coconut wastes (Table 15). Forty-five percent of the people surveyed said they used coconut wastes in the summer as well as the monsoon/winter. (The tendency is to collapse these two seasons together as the cold weather generally coincides with the rains). All parts of the coconut tree are used: fronds, stalks, inflorescence, husk. Other crop residues such as mulberry, castor, and pigeon pea wastes are used but to a lesser degree. The second most common fuel used in the summer is dung (32 percent). In winter, "whatever fuel is stored" is second most commonly used fuel (23 percent). Cut wood of various types occupies the third position in all seasons (17 percent in the summer, and 22 percent in the winter/monsoon). People use a greater variety of fuelwood in the south; larger pieces of wood are burned more frequently also. Common fuelwood species include acacia nilotica, prosopis juliflora, ficus bengalensis, pongamia glabra, and madhuka longifolia.

People in Keelara and Pallerayanahalli depend on their own sources for cooking fuel and relatively few families buy any sort of cooking fuel. Almost an equal percentage of households gather fuel or obtain it from their own property (33 percent and 29 percent) (Table 16). Seventeen percent said they bought their cooking fuel. The remaining twenty percent or so depended on a combination of sources for their cooking fuel, the largest group being those who rely partly on their own sources of fuel and partly on purchased fuel (8 percent).

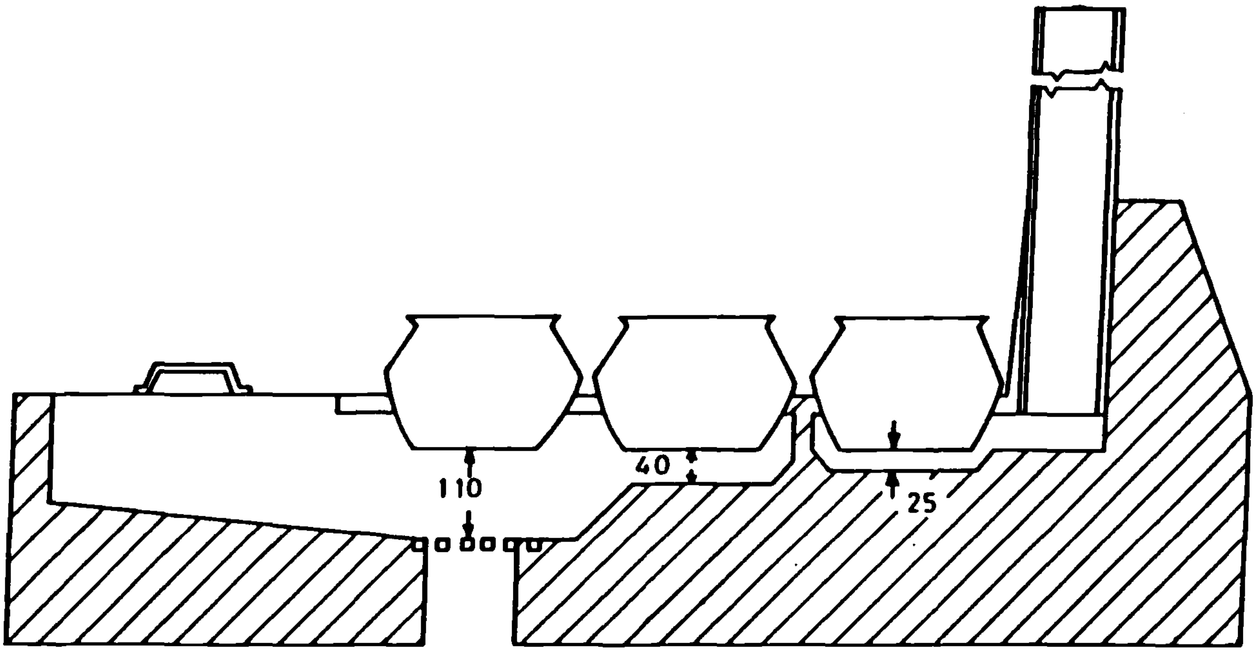


Figure 5. A cross-section of the ASTRA ole
(from ASTRA, 1987)

Table 13. Types of Stoves in Use in Keelara and Pallerayanahalli

Stove type	n[a]	%
Traditional one port[b]	35	35
Traditional two port	16	16
Traditional three port	26	26
ASTRA	52	52
Electric	2	2
Traditional one port w/ chimney	2	2
Traditional two port w/ chimney	3	3
Traditional three port w/ chimney	23	23
Kerosene	15	15
Three brick	1	1

[a] Total n = 100. The column totals do not add up to 100 since some households use more than one stove regularly.
[b] These stoves are used primarily of heating bathwater and tasks such as making castor oil, rarely for cooking.

Most people travel a distance of 2 km (one-way) to gather their cooking fuels. This is usually not a trip made specifically to gather fuel; people often gather cooking fuels on their way back from the fields or when herding animals. Most people gather fuel two or three times a week. About 20 percent said it was a daily chore. Most often the cook herself is responsible for gathering fuel. Others who share the responsibility are the head of the household or the son or daughter of the family. Daughters-in-law are rarely sent on fuel-gathering missions.

One difference between these villages and Garhibazidpur is that there is a market for crop residues, in the sense that coconut shells and husks are bought and sold by the cartload. There is a coconut "trade" as there is a great demand for tender green coconuts in towns and cities. The use of crop residues is more prevalent in the summer when a wide variety of residues are available--castor twigs and pigeon pea wastes are most abundant. Almost 60 percent of the households obtain residues from their own fields. Fifteen percent said they were able to obtain crop residues from large landowners free of cost. About 10 percent said they buy crop residues (these are generally people buying coconut husks).

Rice, ragi balls, and sambar (curry) are the staples in this area. Most people cook twice a day. Breakfast is prepared on a regular basis only in a third of the households. The others let their work schedule determine their morning meal arrangement. Normally, the cooking of breakfast (when it is prepared) and the noon meal is combined. The survey showed that 63 percent of the households prepared rice, ragi, and sambar in the mornings, 28 percent prepared ragi rotis (similar to the rotis of Garhibazidpur, except that these are not made from wheat and these do not have to be placed next to a radiant flame for the last phase of cooking), 10 percent made rice and sambar, and so on (Table 17). Most people (85 percent) do not cook at noon. Those who do normally prepare rice, ragi

Table 14

Stove Use by Purpose or Task in Keelara and Pallerayanahalli

Stove type	All purpose n[a]	All purpose %	Cooking meat n	Cooking meat %	Heating bathwater n	Heating bathwater %	Coffee/ tea n	Coffee/ tea %	Large numbers n	Large numbers %	Occasional use n	Occasional use %	When in hurry n	When in hurry %	Abandoned n	Abandoned %
Traditional one port	3	3	-	-	32	32	-	-	-	-	-	-	-	-	-	-
Traditional two port	11	11	-	-	2	2	-	-	1	1	-	-	-	-	-	-
Traditional three port	20	20	-	-	-	-	-	-	3	3	1	1	-	-	3	3
ASTRA	41	41	-	-	-	-	-	-	2	2	-	-	-	-	6	6
Traditional one port w/ chimney	-	-	1	1	1	1	-	-	2	2	-	-	-	-	-	-
Traditional two port w/ chimney	2	2	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Traditional three port w/ chimney	23	23	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Electric	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Kerosene	-	-	-	-	-	-	5	5	-	-	8	8	3	3	-	-
Three brick	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-

[a]Total n = 100.

Table 15. Cooking Fuel Use by Season in Keelara and Pallerayanahalli (n = 100)

Fuel type	Winter/monsoon[a]	Summer
Coconut[b]	43[c]	46
Stored fuel	23	-
Cut wood	22	17
Aala[d]	16	13
Hongay	13	12
Basri	10	9
Gobli	9	7
Bevu	8	6
Twigs	7	9
Roja	5	-
Dung	-	32
Gathered fuel	-	15
Castor twigs	-	6

[a] Winter and monsoon are collapsed into one category since cold weather usually coincides with the rains.
[b] All parts of the coconut tree are used: fronds, stalks, husk, and inflorescence.
[c] Column totals do not add up to 100 since many households depend on more than one fuel in each season.
[d] Aala = Ficus bengalensis; hongay = Pongamia glabra; basri = Ficus retusa; gobli = Acacia nilotica; bevu = Azadirachta indica; roja = lantana.

Table 16. Means of Procuring Cooking Fuel in Keelara and Pallerayanahalli (n = 100)

Source	Fuelwood	Crop residues
Own	29	59
Buy	17	9
Gather	33	-
Own and buy	8	3
Buy and gather	3	1
Given (gratis)	1	15
Buy and given (gratis)	1	2
Own and given (gratis)	-	1
Own and gather	5	-
Not applicable	3	10

balls, and sambar. The evening meal differs from the morning meal in that no breakfast items are being prepared. Instead, those who have prepared enough sambar in the mornings only have to cook rice and ragi in the evenings (16 percent).

As mentioned earlier, landowners in Keelara feed their agricultural labor during transplanting and harvest. Thirty percent of those surveyed said that in

Table 17. Daily Diet in Keelara and Pallerayanahalli (n = 100)

Food item	Morning	Noon	Evening
Breakfast item	36[a]	-	-
Rice	2	1	3
Ragi	1	-	2
Sambar	-	-	1
Rice and ragi	2	-	16
Rice and sambar	10	-	5
Ragi and sambar	8	-	5
Rice, ragi, and sambar	63	14	65
Do not cook	3	85	5

[a] Column total adds up to more than 100 since more than one meal is being prepared in the morning in some households.

this phase of the agricultural cycle there is no change in the type of meals prepared or in the cooking schedule but that the quantity of food cooked increases. Another 21 percent replied that they were landless and that during these periods they cooked very little. The remaining people said they prepare some breakfast item in the mornings (for the family as well as the laborers), rice, ragi, and sambar at noon, and again in the evening. There seems to be a distinct noon cooking period at least among the larger landowners during these heavy agricultural work periods.

In conclusion, then, one can say that there are some major differences in almost all aspects of the specific environment between the northern village and the southern villages. Firstly, the kitchen has a more ephemeral nature in the Garhibazidpur, that is, its location changes with season and often even with time of day. The Keelara and Pallerayanahalli kitchens, in contrast, are very established and permanent. They are also enclosed spaces as opposed to Garhibazidpur kitchens which are much better ventilated. The stoves, leaving aside the newly introduced improved cooking stoves for the moment, are quite similar, though the Garhibazidpur stove has a single port and the southern stove has three ports. They are basically shielded fires. The primary cooking fuel in Garhibazidpur is a scrub-like acacia, while in the Keelara and Pallerayanahalli it is coconut wastes. In both places, crop residues are important cooking fuels. Dung is an important supplementary fuel in the north and perhaps becoming so in the south. The use of cut wood is limited and very few people buy their cooking fuel. Most people continue to gather their cooking fuels from roadsides and field boundaries. Diet and hence cooking practices are quite dissimilar in the two places. In Garhibazidpur, the making of rotis dominates the cooking routine and determines not only the cook's movements for the duration of the cooking period but also, to a certain extent, the type of stove that can be used and is acceptable. Keelara and Pallerayanahalli have rice- and ragi-based diets. This type of cooking (boiling mainly) does not require the close attention of the cook. However, the type of fuel used here as in Garhibazidpur is quick-burning so this does place some restrictions on the cook's movements. Finally, there are seasonal variations in the cooking schedule in Garhibazidpur but the variations in Keelara and Pallerayanahalli are more influenced by the agricultural cycle.

Chapter 3

METHODOLOGY

In this chapter, the methods of data collection and their evolution are described. As with most field research, the procedures actually followed varied from the ones proposed in the original research design. The reality of the field is always, it seems, more complex than one anticipates, and the complications arise in unexpected quarters. This is probably so regardless of the preparations and precautions of the researcher: in this case, it was my first field experience so there was much to learn.

I had the benefit of two support institutions, the Tata Energy Research Institute in New Delhi and the Indian Institute of Science in Bangalore. With their assistance, the first few months were spent in locating field assistants, organizing transportation, and other practical necessities, as well as in selecting field sites. The latter process was described in Chapter 1. The focus here will be on the subsequent steps.

My main criteria in selecting research assistants were fluency in the local language as well as ability to communicate in English, willingness to learn the basic operation of the air pollution monitoring equipment, and willingness to spend considerable amounts of time in the village. While working in Garhibazidpur, we normally stayed in the village four or five days and returned to New Delhi for two. These trips to New Delhi, though disruptive, were necessary in order to charge the batteries of all the air pollution equipment and to weigh filters. In Bangalore, the distances were greater and the electricity supply more reliable so the village stays were extended (10 days to two weeks). I slept at the Indian Institute of Science's extension centre about 5 km from Keelara; ideally, I would have stayed in the village itself and for longer periods in both places. That would have given me a better empathetic understanding of life in the village. But a compromise had to made between such immersion in village life and activities and a relatively systematic quantification of air pollution concentrations and exposures.

Sample selection for air pollution monitoring and opinion survey

A village house-list was obtained and every fifth household was visited. Information collected during this preliminary survey included:

* number of family members

* number, type(s), and use(s) of stove(s)

* kitchen type (i.e. location, ventilation characteristics, and construction materials)

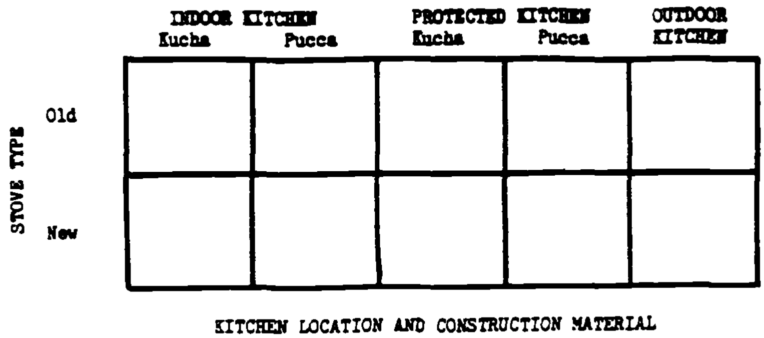
* commonly used cooking fuels

* cooking schedule and seasonal variation in schedule

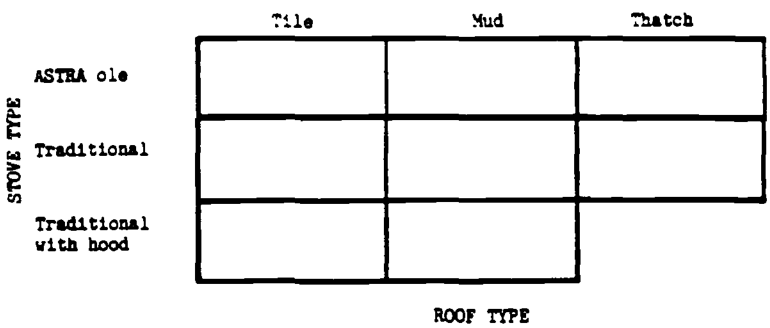
* diet and seasonal variation in diet

On the basis of the results of this survey, a sample was chosen for monitoring of air pollution within kitchens.

In Garhibazidpur, the variables by which the sample was organized were kitchen location, kitchen construction material, and stove type. The diagram below shows how this worked out:



As everyone cooks indoors in Keelara, the main variables there were construction material of the kitchen roof and stove type. The diagram below shows the sample in Keelara:



In the first round of data collection (summer season data), three readings were taken in each cell. This was expanded to five readings in the monsoon season data collection as the variation among readings was found to be large. In the third round of data collection (winter season data) five readings per cell were taken as well. This increase in sample size did not completely compensate for the variability in the data but time and financial constraints prevented any further expansion of sample size.

Altogether, 45 households were monitored in Keelara, ten in Pallerayanahalli, and 42 in Garhibazidpur. The total number of monitoring sessions was as follows: Keelara, 83; Pallerayanahalli, 21; and Garhibazidpur, 87. According to the study design, an opinion survey was to be carried out in 100 households in the northern and southern villages. This survey was conducted in all the households in which air pollution monitoring was done. The remaining households were randomly chosen from the village house list. Due to logistical problems in the north only 62 of these surveys were completed. In the south, the households in Pallerayanahalli that were monitored made up part of the 100 households surveyed.

Air pollution monitoring procedure

The first application of personal air pollution monitoring in a rural developing country setting occurred in 1981 when a pilot study of indoor (domestic) air pollution in Gujarati villages was done (Smith et al., 1983). The air pollution monitoring protocol used here is very similar to the one used in that study. The major differences are that in Gujarat the sample sizes were smaller, there was no stratified sampling for household selection, the entire cooking period was not measured, stationary sampling was not done, there was no attempt to collect seasonal data, and the number of improved cookstoves tested was small. The Gujarat filters were subjected to chemical analysis for benzo(a)pyrene. The object in Gujarat was to determine if indoor air pollution is indeed a problem in rural areas of developing countries. The aim here is to describe the cultural and environmental parameters affecting exposures to TSP and CO.

The monitoring procedure that was followed is outlined below and discussed at greater length in the following pages:

1) The cook was asked to set aside the fuel that she expected to use to prepare the meal. The weight was noted and any additional fuel used subsequently was weighed as well.

2) An anemometer was placed outside the house to record windspeed and the temperature and humidity in the cooking area were noted.

3) The stationary samplers were positioned adjacent to the cook.

4) The cook was fitted with the gravimetric sampler.

5) The empty cooking vessels were weighed (Keelara and Pallerayanahalli only).

6) When the cook ignited the fire, the sampler and stationary monitors were switched on.

7) The stationary monitor readings were recorded every 60 seconds. The cook's movements and her operation of the stove were noted.

8) When cooking was completed and the cook had extinguished the fire, the sampler and stationary monitors were switched off.

9) The remaining fuel and the pots containing the cooked food were weighed.

10) The anemometer reading and the temperature and humidity in the cooking area were noted once again.

11) The filter cassette containing the exposed filter paper was closed and sealed.

A personal gravimetric sampler (Gilian, Model 113) was used to measure the exposure of the cook to TSP. The cook wore the sampler pump at her waist; the pump pulled air from her breathing zone through a 37mm Pallflex teflon-coated glass fibre filter paper. The filter paper was held in place by a cassette holder which was pinned to the shoulder of the cook's blouse. The cassette holder was used in the open-faced mode to ensure isokinetic sampling.2 The pump has an inbuilt rotameter and the flow rate was set at 3.0 lpm to collect as large a sample as possible. The pump was turned on as soon as the cook ignited the cooking fire. Sampling continued until cooking was completed and the fire extinguished. The filter paper was weighed before and after sampling; the difference in weight gave the mass of suspended particulate matter collected. A set of control filters was kept to monitor any change in filter weights unrelated to air pollution monitoring.

The control filters were treated in exactly the same way as the experimental filters except they were not used. They were equilibrated and weighed along with the experimental filters and they were taken to the "field". There were seven control filters for every group of 33 experimental filters. A total of 400 filters were taken to India -- 70 of these were controls. The average change in weight in each set of control filters was used to adjust the observed changes in weight in the corresponding set of experimental filters.

Data on concentrations of TSP and CO in the cooking area were obtained using stationary monitors. The CO detector (Gastech CO-82) used an electrochemical cell and had a liquid crystal digital display, and the TSP monitor's (Miniature Real-time Aerosol Monitor, Model PDM-3, GCA Corp.) operating principle was based on the detection of scattered infrared light. These monitors were placed adjacent to the cook at about her squatting breathing-height. CO readings were taken at 60-second intervals. The TSP monitor was capable of giving a time-weighted average at the end of the measurement period.

The gravimetric sampler was calibrated every day using a bubble meter. The electronic TSP monitor was cleaned and the zero checked and reset periodically. The CO monitor was calibrated periodically using span gas obtained in New Delhi.

The cook was asked not to alter her normal behavior as far as possible. This, of course, was made difficult by our presence and the unfamiliarity of the measuring devices. No restriction was placed on the type of cooking fuel used. Whenever possible, the measurement was repeated at least once in every household.

In all, three rounds of data were collected each in Garhibazidpur and Keelara (Figure 6). The monitoring sessions in Garhibazidpur were conducted during April, August-September, and December-January. In Keelara, the sessions were conducted in July, October-November, and February-March. In Garhibazidpur,

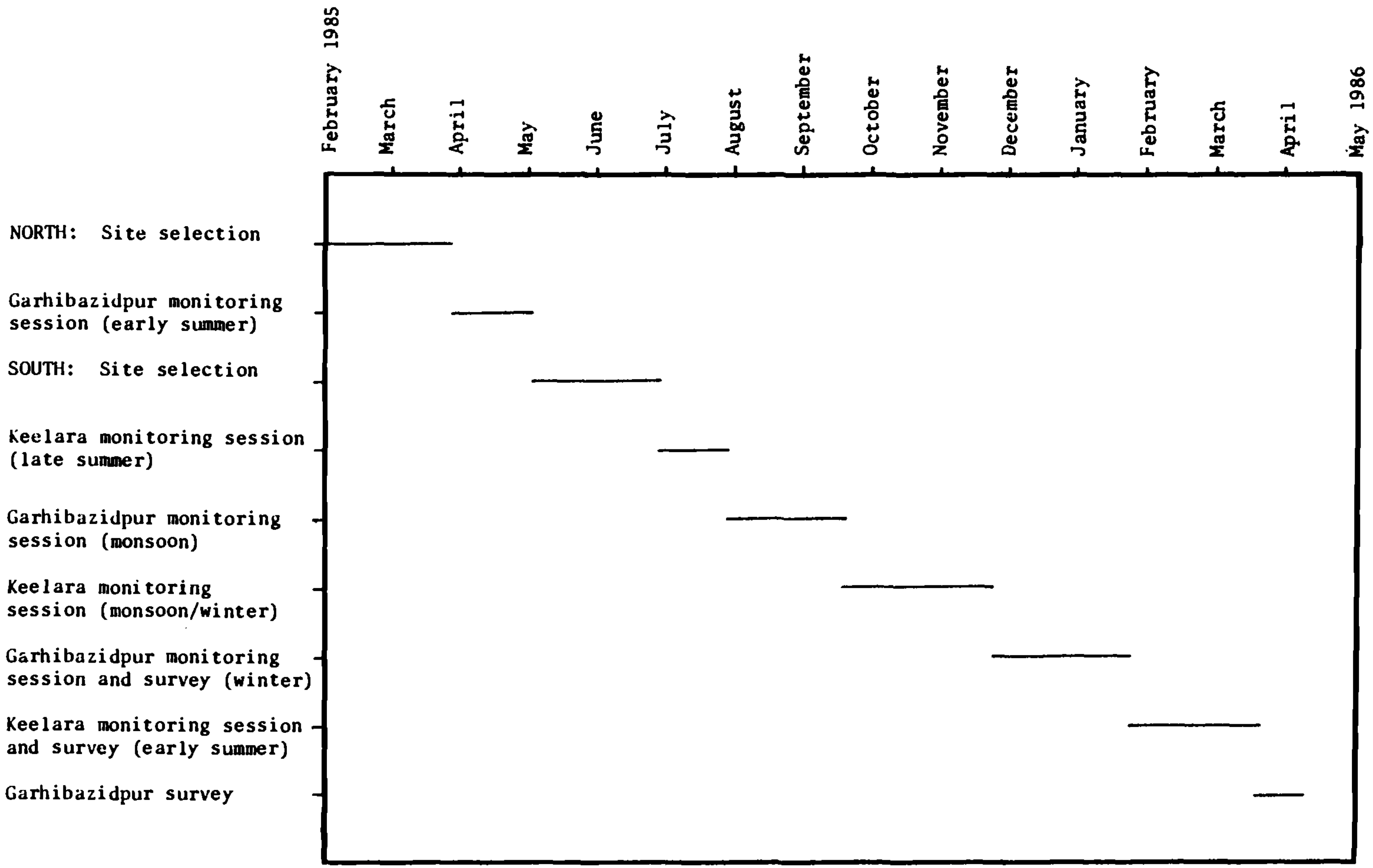


Figure 6. Field study schedule, February 1985-April 1986

this schedule coincided with the early summer, late monsoon, and winter seasons. In Keelara and Pallerayanahalli, the corresponding seasons were late summer, late rain/winter (second rainfall peak), and early summer. Since rainfall was very low in both places that year, there was no real change in the type of fuel being used or in the moisture content of the fuel as might have been observed in a "normal" year.

Lastly, once the measurements were complete, a decision had to be made regarding which set of filter weights was to be used in the analysis. All the filters were weighed in Honolulu prior to departure since the availability of a precise enough (able to weigh to a thousandth of a gram) balance in the field was not certain. As it turned out, access to sufficiently precise balances was not a problem in either Delhi and Bangalore. Hence, the filters were weighed twice in the field, once immediately before usage and once immediately after. All the filters were weighed for a fourth time on return to Honolulu, on the original balance.

One of the problems of field measurements of TSP exposures using personal gravimetric samplers is the time lag between pre-weighing, exposure, and post-weighing. There is concern that the filter may gain moisture (though the teflon-coated filters are 98-percent moisture resistant), or that they may be contaminated in some way or lose collected material in handling, storage, and transportation. To minimize the risk of the latter, the filters were sealed individually in plastic bags and stored in airtight containers immediately after the postweight was taken in the field. To compensate for the possibility of moisture absorption, all the filters were equilibrated before each weighing. The filters were placed in a tray lined and covered with aluminium foil. The cover had small perforations to allow the passage of air while protecting the filters from settling dust. This tray containing filters was kept in an air-conditioned room for 24 hours before each weighing. This was to allow the filters to reach equilibrium before weighing.

There were, then, four weighings for each filter: Honolulu preweight, field preweight, field postweight, and Honolulu postweight. The question of which set of figures should be used arose. If the change in filter weights according to the Honolulu measurements (Honolulu2-Honolulu1) is compared to the change according to the field measurements (Field2-Field1), it is clear that though the aggregate change for the Honolulu weights is greater, the variability is smaller (Table 18). The advantage of using the field weights is that there is a shorter time lag between preweighing, exposure of the filter, and postweighing, and hence less opportunity for contamination of the filter. The data seem to indicate, however, that the field balances were not very accurate and that they "drifted" considerably during the study period. A T-test for matched pairs was done and this shows that the two sets of weights are indeed significantly different. Based on these considerations, it was decided to use the Honolulu weights in reporting the results. It might be added that the results and conclusions do not change depending on the set of weights used though the confidence level does alter.

<u>Opinion survey</u>

The survey used a written questionnaire but the interview was not formal and took the form of a conversation rather than an interrogation. Most of the

Table 18. Analysis of Variation in Filter Weights

	Honolulu postweight-Honolulu preweight (g)	Field postweight - Field preweight (g)	p[a]
Garhibazidpur			
n	93	93	
mean	0.00058	0.00053	p<0.05
standard deviation	0.00030	0.00034	
coefficient of variation	0.52	0.66	
Keelara and Pallerayanahalli			
n	103	103	
mean	0.00061	0.00049	p<0.01
standard deviation	0.00041	0.00043	
coefficient of variation	0.67	0.88	

[a] Two-tailed T-test.

questions were open-ended. The questionnaires used in the north and south were slightly different and were adapted to include queries about cooking practices and fuel use patterns unique to each place. The questionnaire was pre-tested in each place and changes made according to the findings. Copies of both questionnaires are appended (Appendix A).

Initially, a team of two conducted the survey, myself and an assistant. The assistant would carry on the conversation, I would record the answers, interjecting occasionally for clarification or further comment. When I became confident of my ability to communicate, and the assistant of his/her ability to conduct the interview independently, we went individually to households. The "interview" usually lasted 20 minutes to half-an-hour and everyone present in the house came to listen and contribute their opinions. The advantage of such participation was that it encouraged discussion without any prompting from the "interviewer". On the other hand, there was also the danger of a less assertive "interviewee" being overwhelmed by majority opinion.

The questions concerned fuel use preferences and patterns, uses of the stove, cooking practices, diet, perceptions of air pollution, and remedial action taken by householders to alleviate air pollution. The "informational" questions were quite straightforward, easy to put, and people seldom hesitated in answering them. The perception questions ("Does smoke from the stove bother you?") were less easy to communicate. Often, the initial response was "No" but later on, when the question "Do you find that smoke from the stove is helpful in some ways?" was put, the women responded by enumerating the various disbenefits of having smoke in the house. For example: "Of course, it is not a benefit. How can it be? It blackens the walls and irritates the eyes! It is a problem not a benefit." The strategy in conducting the survey soon became to leave the answer to the question "Does smoke from the stove bother you?" unrecorded until the question on the benefits of smoke had been asked.

Previous studies have found that people associate air pollution with visible deterioration of environmental quality and think of health impacts only when questioned specifically about it:

> Most people did not define air pollution in terms of a health hazard until asked specifically if it was harmful to health. An overwhelming majority then said yes. He (Crowe, 1967) suggests that the more tangible and observable features (eg., smoke, dirt) may be masking a more abstract, but real, concern regarding the possible effects of air pollution (Barker, 1976).

This is probably changing in more developed countries as people become more health conscious. In the case of domestic air pollution in developing countries, however, the shortterm health impacts are quite obvious and people needed no prompting to relate them. The long-term health impacts are less easy to discern and no attempt was made to estimate them using this questionnaire.

Besides these relatively formal methods of trying to understand how people perceive air quality and related matters, there were also the very informal conversations that took place with the cooks and other women during the monitoring sessions. Once the equipment was set up and the cooking routine underway, there was often plenty of time to talk. The conversation was spontaneous and generally revolved around the women's life and work in the household and in the field. Summaries of the relevant portions of the conversation were recorded on the monitoring session data sheets (for a sample of this sheet, see Appendix B).

Critique of methods

The usual tendency in field studies of air pollution is to focus either on the quantitative details of the nature, concentration, and distribution of the pollutants or on a description of the environmental, cultural, and social circumstances that contribute to the problem. Such restriction of focus may be necessary since gaining an adequate understanding of either facet of the problem is difficult enough in terms of marshalling the time, energy, and resources needed. The practical implications of such an investment became clear in the course of the field study.

Inevitably, a degree of detail and thoroughness is sacrificed when a comprehensive approach is adopted. In return, however, one may obtain a broader view of the problem under study, of the various elements and their interconnections. This was the motive for taking such an approach. There will be many junctures in the data analysis section (Chapter 4) where the inadequacies of this approach will be evident.

The difficulties of collecting qualitative as well as quantitative data were compounded by having two field sites a thousand miles apart. It added travel time and expense to the study. On the other hand, the comparison of the two places, so very disparate in many ways, was useful and helped clarify the variables of interest in each place. It was also, as it happened, a good strategy to have these breaks in the data collection schedule: it gave our "subjects" much-needed respites from us and our activities.

The major problem with air pollution monitoring lay in conducting repeat monitoring sessions in households. Our presence in kitchens for two to three hours was an intrusion. Besides the inconvenience, people often objected for reasons that I was not quick to perceive. Once the households were selected, the sessions proceeded on a random schedule. When the time arrived for the first set of repetitions, we met with resistance in more households than I had expected. In all these households, our initial welcome had been warm and even enthusiastic. My assistant then pointed out that we had in our first round of monitoring alternated freely between high and low caste houses, a practice unacceptable to most high caste households. This sort of faux pas could have been avoided had I been more sensitive to the realities of village society. As it was, scheduling monitoring sessions became a much more complicated and time-consuming activity and the study suffered due to it.

A problem associated with seasonal or longitudinal studies is that it is difficult to control all the variables of interest throughout the study period. We tried to return to the same households as far as possible in different seasons and monitor the same cook using the same stove. This turned out to be unexpectedly complicated. Besides the reasons already mentioned, the woman with the primary responsibility for cooking was not always the same, as women periodically returned to their maternal homes or married and moved away. The operator of the stove was often different every monitoring session. Apart from the need for a seasonal overview, measurements were repeated to allow cooks to become more accustomed to the equipment in the expectation that their behavior in subsequent sessions would be more spontaneous and natural. This was a hypothesis that could not be tested, however, as the cooks kept changing.

Another consideration in the monitoring routine related to the diurnal variations in ambient air pollution and micrometeorology which might affect morning and evening sessions differently. Originally, the plan was to repeat each house once in each season to obtain one morning and one evening-meal reading. This was done in the first round of data collection in Keelara and no observable difference could be found between morning and evening readings. Subsequently, the repetition in each season was abandoned as an added burden.

Finally, though the measuring devices used were specifically designed for the purpose of measuring occupational exposures, they had their limitations which affected the method of data collection as well as the quality of data. The shortcomings of using a filter-equipped gravimetric sampler have already been discussed. Further, despite the device's portability it is an obtrusive instrument to use. The woman cooking has to wear the sampler pump at her waist which can be uncomfortable as most cooks squat on the ground. The pump is noisy so it is difficult for the person wearing it to forget its presence and to behave naturally, cooperative though they may be. Against these disadvantages must be weighed the fact that using the gravimetric personal sampler is the most effective way presently available to measure personal exposure to TSP.

The stationary samplers for area monitoring presented different problems. Both the CO and TSP monitors proved to be extremely sensitive to their placement in relation to the stove and to the ventilation facilities and to minute changes in the micrometeorology. This was particularly true of the CO monitor which, it was discovered, is also sensitive to light. Finally, it was difficult to standardize their placement due to the variety in kitchen design and the lack of space in many kitchens. Therefore, the area monitoring data must be viewed with some caution.

As far as the opinion survey is concerned, the principal improvement that could be made is in the questionnaire. Inspite of pretesting, the questionnaires were not as streamlined as they might have been. Several redundancies came to light as the survey was carried out. Some informational questions (for example, the seasonal pattern of crop residue use) yielded uniform answers and could have been eliminated fromthe final questionnaires. On the other hand, it is evident now that the perception questions could have been developed further. Attitudes are very difficult to characterize on the basis of answers to a few brief questions. A compromise had to be reached, however, between the length of the questionnaire and the quality of the data collected.

Observed Discrepancies Between Measurement and Perception

This study tried to collect data on both the physical manifestations of indoor air pollution as well as people's perception of it. The difficulties of the latter portion of the study relate basically to the discrepancies between measurement and perception, and the pitfalls of collecting information on perception. Two major discrepancies between measurement and perception are apparent in the data. First is the issue of fuel use. As Chapter 4 shows, the weighing of fuel during the monitoring sessions revealed no difference in fuel use between the old and the new stove in the north and only a slight one in the south. The cooks in the south, however, were unanimous in their opinion that the new stove used less fuel. Why the disagreement between measurement and perception? A possible explanation is that since people tended to associate the survey with the Indian Institute of Science extension centre, they may have assumed we wished to hear positive comments about the stove, and proceeded to tell us what we ostensibly wanted to hear. Alternatively, people may be inclined to view the new stove more favorably since it does not use more fuel than the old one, it is more effective in removing smoke from the cooking area, and it is currently in place in the kitchen. Having decided to adopt the new stove, householders may be disposed to exaggerate its qualities or assign it ones it does not possess. Another explanation might be that our measurement techniques were faulty and we overestimated the consumption of fuel in the improved cookstove. That is unlikely, however, since the same measurement techniques were applied in all households, regardless of the type of stove in use.

A second measurement versus perception issue is the perception of air pollution. Though the measurements show that concentrations of and exposures to air pollutants are high, there is no parallel unanimity of response to the question "Does the smoke bother you?" (65-75% answered in the affirmative). The explanation that comes most readily to mind is that indoor air pollution in rural areas of developing countries is such a longstanding condition that it is part of the background, a circumstance that people accept as inescapable and ignore most of the time. Another explanation for the lack of agreement is the fact that apart from the temporary irritation of watering eyes, people do not perceive the ill-effects of air pollution. The time lag between exposure and any health effect is so long that no connection is made and, hence, the seriousness of air pollution when seen against all the other hazards that people have to face in rural areas seems quite minimal.

Sources of Bias

As has been observed by many researchers in the past, by studying a phenomenon or situation we often change its nature. In this study, for example, the fact that fuelwood is being weighed and questions are being asked about smoke from the stove will affect people's behavior. If people think one is interested in smoke, they may purposely make the kitchen smoky. Conversely, they may perceive that one views the smoke as undesirable and endeavor to make the kitchen less smoky. This sort of participant bias is not only difficult to control but difficult to measure. Much depends, of course, on the objectivity with which the study is conducted. No matter how non-committal the interviewers are, it is difficult not to convey some impression of personal opinion and prejudice and to avoid researcher bias. Furthermore, it is difficult in retrospect to determine the extent and direction of these influences. How was the response of a cook using a new stove influenced? How did this differ from the bias of a cook using an old stove? We made an effort to be evenhanded in our dealings with households using all types of stoves by not speaking in favor of any stove type and by making it clear that we had not been involved in the dissemination of the new stove. Given these conditions, it is just as likely that the cook will try to demonstrate that her new stove is efficient and smokeless as the reverse. On the other hand, it was not a blind study -- we knew which were the improved cookstoves and which were not. Subconsciously, this knowledge may have affected our behavior. As there can be no certainty or strict quantification of bias, perhaps the best that can be done is to be cautious in interpreting the data.

If the object of the exercise is to obtain as integrated a view as possible of a problem such as this, with so many physical, social, and cultural variables, one must utilize qualitative as well as quantitative methodologies. Unfortunately, sometimes the requirements for the one create suboptimal conditions for the implementation of the other. Nonetheless, an imperfect amalgamation of the two results in a richer data set than either one alone.

Chapter 4

DATA ANALYSIS AND RESULTS

Much time and labor were invested in data collection, as described in the methodology section, but the eventual sample sizes were still relatively small, and these proved to be insufficient to overcome the large natural variability in the data. This limited the kinds of analysis that could be performed and the conclusions that could be drawn. Analysis was limited to descriptive statistics, analysis of variance, tests of correlation, and T-tests. These procedures did not always yield conclusive results but the exercise was instructive in itself, making the characteristics of the data as well as its limitations clear. Therefore, the process of analysis, possible explanations of the results, and the problems of analysis are presented here. Variability of data, apparently an inherent feature of field studies such as this (Smith and Durgaprasad, 1987), has important implications for the design of future studies which will be discussed in Chapter 6.

Analytical Procedure

The data were analyzed with the purpose of trying to relate measured TSP exposures and CO concentrations to the contrasting environmental and cultural characteristics of each of the study areas. The object was to try to arrive at a quantitative estimate of the influence of such factors as stove type, kitchen location, kitchen construction materials, roof type, and fuel type. Elements of the microenvironment such as relative humidity and ambient temperature were also considered. Not measured but recognized as important were wind speed and operator behavior. The latter was difficult to characterize and quantify but could conceivably be reduced to quantifiable components of behavior such as feeding rate of the fire. The same procedure was followed in analyzing data from Garhibazidpur and from the southern villages since the data were gathered similarly and shared common characteristics.

The initial intention was to follow the same households through three measurement periods covering summer, monsoon, and winter seasons so as to gain an overview of seasonal variation. This proved to be extremely difficult for a variety of reasons. Most householders were cooperative during the first measurement session but it was difficult to convey to them the need for subsequent monitoring sessions. Sometimes scheduling problems could not be overcome. In a few houses, the domestic situation was such that sessions could not be arranged. Mothers-in-law and husbands often had objections to what was, after all, an intrusion into the household and a disruption of the routine. Finally, some did not appreciate the fact that monitoring was done randomly regardless of caste. Several of the households were repeated in two measurement periods. Some were repeated in the same measurement period (almost all these repetitions occurred in measurement period 1) to determine whether there was any difference between morning and evening measurements.

Figures 7 and 8 show the particulars of the sample in the northern and southern villages in each measurement period. It must be pointed out that some unavoidable changes occurred in the households over time. In the north, kitchen location often changed between measurement periods and in both the north and the south, the stove and the cook often were different in consecutive measurement periods for various reasons. These changes are part of the normal routine that I wanted to disrupt as little as possible and which, in any case, were unavoidable in some instances. The replicates were "true" replicates (i.e., with no change in the variables of interest) only in the case of three households in the north and six in the south. Even including households where some change occurred, measurements were taken in all three periods in only 10 households in the north and in 17 households in the south.

The whole sample (n=103) was not used in the analysis for the southern villages since CO readings were missing for two records and the outlier detector test identified one outlier in the data. Hence, the analysis for the southern villages was limited to one hundred records. All the records from the northern village (n=87) were included in the analysis.

Descriptive statistics were compiled for both these data sets and the results show highly skewed and kurtotic distributions of TSP and CO (Tables 19 and 20). A natural log transformation was used to correct for this. Half of the detection limit of the measuring devices was used where there were zeros in the data. It was found that the data more nearly approached a normal distribution when a constant was added to each data point before carrying out the log transformation (this amount was again subtracted after back transformation when computing descriptive statistics). Various constants were tested and it was found that skewness was most reduced when a constant of 1 mg/m3 was added to the data from Garhibazidpur and a constant of 0.5 mg/m3 added to the data from the southern villages. Since the object of the exercise was to arrive at a normal distribution so that various analytical tests could be carried out, the log-transformed data with the constant were used. The stages of these manipulations for the Garhibazidpur data can be seen in Figures 9 and 10 which show the differences in skewness and kurtosis between the raw data, the log-transformed data, the data with a constant of 0.5 mg/m3 added before log transformation, and the data with a constant of 1 mg/m3 added before log transformation.

A further problem that had to be resolved regarded the legitimacy of using repeated measurements. Since several measurements were taken in some households it was questionable whether all the measurements could be treated as independent data points. Tables 21 and 22 summarize the results of an analysis of variance of TSP data from Garhibazidpur, and from Keelara, and Pallerayanahalli. In both cases, the analysis showed that variation within households, i.e., between successive measurements in the same household, was greater than variation among households. Hence, it was concluded that the measurements could be treated as independent data points. This implies that measurements taken in one time period

Stove	Kitchen Location	Kitchen Construction Material	Measurement Period 1	Measurement Period 2	Measurement Period 3
TRADITIONAL n=51	Indoor	Kucha	1	5	5
		Pucca	-	2	6
	Protected	Kucha	1	4	6
		Pucca	1	4	5
	Outdoor		2	4	5
IMPROVED n=36	Indoor	Kucha	1	2	1
		Pucca	1	6	5
	Protected	Kucha	1	1	-
		Pucca	1	4	5
	Outdoor		2	5	1
			n=11	n=37	n=39

Figure 7. Garhibazidpur samples in the three measurement periods

Stove Type	Roof Type	Measurement Period 1	Measurement Period 2	Measurement Period 3
IMPROVED n=38	Tile	4	4	4
	Mud	3	5	5
	Thatch	3	5	5
TRADITIONAL n=38	Tile	3	5	5
	Mud	3	5	4
	Thatch	3	5	5
TRAD W/ HOOD n=24	Tile	3	5	5
	Mud	3	5	3
		n=25	n=39	n=36

Figure 8. Keelara and Pallerayanahalli samples in the three measurement periods

Table 19. Distribution of Original TSP and CO data in Garhibazidpur

	TSP	CO
Sample size	87	87
Maximum	8.05 mg/m3	35 mg/m3
Minimum	0.01	0.04
Arithmetic mean	3.1	7.9
Standard deviation	1.8	6.1
Skew	0.80	1.38
Kurtosis	0.52	1.9

Table 20. Distribution of Original TSP and CO data in Keelara and Pallerayanahalli

	TSP	CO
Sample size	100	100
Maximum	10 mg/m3	150 mg/m3
Minimum	0.01	0.02
Arithmetic mean	2.6	14
Standard deviation	2.0	19.0
Skew	1.76	3.55
Kurtosis	3.29	15.02

in a given household cannot be used to predict TSP levels at later time periods in that same household and that, possibly, taking measurements at different times in the same household can be equated with taking measurements in different households in the same time period. These are important considerations in designing future studies and in attempting to understand the natural variability of the data.

Results of Air Pollution Measurements

Table 23 and Figures 11, 12, 13, and 14 summarize the data by stove type. A general model analysis of variance was carried out on these pollutant data and the results are shown in Tables 24, 25, 26, and 27. As might be expected, the general model explained very little of the variation in the TSP or CO data from Garhibazidpur (R2=.20, .35). There were obviously unmeasured factors such as wind speed and operator behavior that were probably playing an important role. The model constructed for the data from Keelara and Pallerayanahalli explained more of the variation, particularly in the case of the CO data (R2=.44, .65).

The object of the analysis of variance was to see if the variance in the TSP exposures and CO concentrations could be explained by the type of stove being

```
VARIABLE: TSP (INTERVAL)          i.  Original field data
SKEW     (z**3/n)      .80
KURTOSIS (z**4/n)-3    .52

                                        HISTOGRAM
   Midpoint                                                                                                          freq   %
      0.58 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                                                            9  10
      1.73 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[            23  26
      2.88 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[ 26  30
      4.03 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                              15  17
      5.18 [[[[[[[[[[[[[[[[[[[[[[                                                                                6   7
      6.33 [[[[[[[[[[[[[[[                                                                                       4   5
      7.48 [[[[[[[[[[[[[[[                                                                                       4   5
-------------------------------------------------------------------------------------------------------------------------------
VARIABLE: LOGTSP (INTERVAL)       ii.  Natural log of original data
SKEW     (z**3/n)    -3.27
KURTOSIS (z**4/n)-3  12.08

                                        HISTOGRAM
   Midpoint                                                                                                          freq   %
     -4.13 [[[[[[                                                                                                    3   3
     -3.17                                                                                                           0   0
     -2.22                                                                                                           0   0
     -1.26 [[[[[                                                                                                     2   2
     -0.3  [[[[[[[[[[[[                                                                                              5   6
      0.65 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[            36  41
      1.61 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[ 41  47
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Figure 9. Garhibazidpur TSP data transformations

```
VARIABLE: LNTSP (INTERVAL)
SKEW     (z**3/n)    -1.08
KURTOSIS (z**4/n)-3  1.86
```

iii. Constant of 0.5 added before log transformation

```
                                        HISTOGRAM
 Midpoint                                                                                                          freq  %
   -0.47 [[[[[[[[[[[[[[[[                                                                                            4   5
   -0.07 [[[[                                                                                                        1   1
    0.33 [[[[[[[[[[[[[[[[[[[[                                                                                        5   6
    0.74 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                           16  18
    1.14 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[   27  31
    1.54 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                       22  25
    1.94 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                                           12  14
---------------------------------------------------------------------------------------------------------------------------
```

```
VARIABLE: TESTTSP (INTERVAL)
SKEW     (z**3/n)     -.65
KURTOSIS (z**4/n)-3    .83
```

iv. Constant of 1.0 added before log transformation

```
                                        HISTOGRAM
 Midpoint                                                                                                          freq  %
    0.17 [[[[[[[[[[[[[[[[                                                                                            4   5
    0.48 [[[[[[[[                                                                                                    2   2
    0.79 [[[[[[[[[[[[[[[[[[[[[[[[[[[[                                                                                7   8
    1.11 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[       26  30
    1.42 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[   27  31
    1.73 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                                           12  14
    2.05 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                                                        9  10
---------------------------------------------------------------------------------------------------------------------------
```

Figure 9 (continued). Garhibazidpur TSP data transformations

```
VARIABLE: CO (INTERVAL)          i.  Original field data
SKEW     (z**3/n)     1.38
KURTOSIS (z**4/n)-3   1.90

                                   HISTOGRAM
   Midpoint                                                                                                            freq  %
      2.13 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[  37  43
      6.32 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                 27  31
     10.52 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                                                                11  13
     14.72 [[[[[[[[[[[[[[                                                                                                    5   6
     18.91 [[[[[[[[[[[[[[                                                                                                    5   6
     23.11 [[                                                                                                                1   1
     27.3  [[                                                                                                                1   1
-----------------------------------------------------------------------------------------------------------------------------------
VARIABLE: LOGCO (INTERVAL)       ii.  Natural log of original data
SKEW     (z**3/n)    -1.17
KURTOSIS (z**4/n)-3   1.64

                                   HISTOGRAM
   Midpoint                                                                                                            freq  %
     -3.01 [[[                                                                                                           1   1
     -2.03 [[[[[[[[                                                                                                      3   3
     -1.05 [[[[[                                                                                                         2   2
     -0.06 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                                                     12  14
      0.92 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                                 18  21
      1.91 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[  33  38
      2.89 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                                 18  21
-----------------------------------------------------------------------------------------------------------------------------------
```

Figure 10. Garhibazidpur CO data transformations

```
VARIABLE: LNCO (INTERVAL)
SKEW     (z**3/n)     -.36
KURTOSIS (z**4/n)-3   -.67
```

iii. Constant of 0.5 added before log transformation

```
                                  HISTOGRAM
 Midpoint                                                                                                                      freq  %
    -0.35 [[[[[[[[[[[[[[[[[[[[[[[[[                                                                                               5   6
     0.23 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                                                     10  11
     0.81 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                                           12  14
     1.38 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                            15  17
     1.96 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[    23  26
     2.53 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                                 14  16
     3.11 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                                                                8   9
```

```
VARIABLE: TESTCO (INTERVAL)
SKEW     (z**3/n)     -.16
KURTOSIS (z**4/n)-3   -.86
```

iv. Constant of 1.0 added before log transformation

```
                                  HISTOGRAM
 Midpoint                                                                                                                      freq  %
     0.27 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                                                        8   9
     0.75 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                                12  14
     1.24 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                              15  17
     1.72 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                    14  16
     2.21 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[    19  22
     2.69 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                          13  15
     3.17 [[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[                                                                                    6   7
```

Figure 10 (continued). Garhibazidpur CO data transformations

Table 21. ANOVA on TSP data from Repeated Households in Garhibazidpur

	Sums of squares	Degrees of freedom	Estimate of variance	F
Total SS	7.9834	N-1=48		
Between SS	4.3166	K-1=21	0.20555	
Within SS	3.6668	N-K=27	0.13581	1.5135

$F_{21,27} = 2.03$

Table 22. ANOVA on TSP data from Repeated Households in Keelara and Pallerayanahalli

	Sums of squares	Degrees of freedom	Estimate of variance	F
Total SS	17.038	N-1=54		
Bewteen SS	9.709	K-1=23	0.422170	
Within SS	7.328	N-K=31	0.236395	1.7858

$F_{23,31} = 1.89$

used or by other environmental and cultural factors such as burn rate, fuel type, kitchen construction material and location, roof type, cooking practices and diet. Though it appeared that these factors have varying degrees of influence on observed exposures and concentrations, it was clear that quantifying the extent of this influence would be extremely difficult. None of the variables included in the ANOVA on the TSP data from Garhibazidpur appeared to be responsible for the variations in TSP exposures while the ANOVA on the CO data showed stove type to be of consequence. Similar analysis of the TSP data from the southern villages revealed roof type, stove type, season and temperature to be important in explaining the variation in the data and the same factors were important in explaining variation in CO concentrations except for season.

These relationships were investigated further using T-tests. The results of these tests are summarized in Table 28. To take the results from Garhibazidpur first, as might have been expected from the outcome of the ANOVA, there was no statistically significant difference in TSP exposure or CO concentration based on stove type or kitchen construction material ($P<0.05$ -- this cutoff point for statistical significance is used throughout the analysis); kitchen location, however, appears to be important in determining CO concentrations. These were

Table 23

Summary of Data by Stove Type

Stove type	(n)	Measurements TSP (n)	Measurements CO (n)	Persons Cooked For (n)	Percent in Evening	Percent Outdoor Kitchens	Sampling Time (min)	Burn Rate (kg/h)	Mean TSP Exposure (mg/m^3) Arith.	Mean TSP Exposure (mg/m^3) Geom.	Mean CO Concen. (mg/m^3) Arith.	Mean CO Concen. (mg/m^3) Geom.
<u>Garhibazidpur</u>												
Sahayog	22	36	36	6.3	47	22	53	1.4	2.9	2.5	6.2	4.2
Traditional	34	51	51	6.2	45	22	46	1.4	3.3	2.9	7.2	5.0
TOTAL OR WEIGHTED AVERAGE	56	87	87	6.2	46	22	49	1.4	3.1	--	6.7	--
<u>Keelara and Pallerayanahalli</u>												
ASTRA	20	38	38	6.1	50	0	58	2.1	2.5	2.0	9.4	4.6
Traditional	24	38	38	5.7	53	0	60	1.9	3.2	2.6	20	12
Traditional w/hood	16	24	24	6.4	50	0	68	2.0	1.7	1.4	5.8	2.7
TOTAL OR WEIGHTED AVERAGE	60	100	100	6.0	51	0	61	2.0	2.6	--	12	--

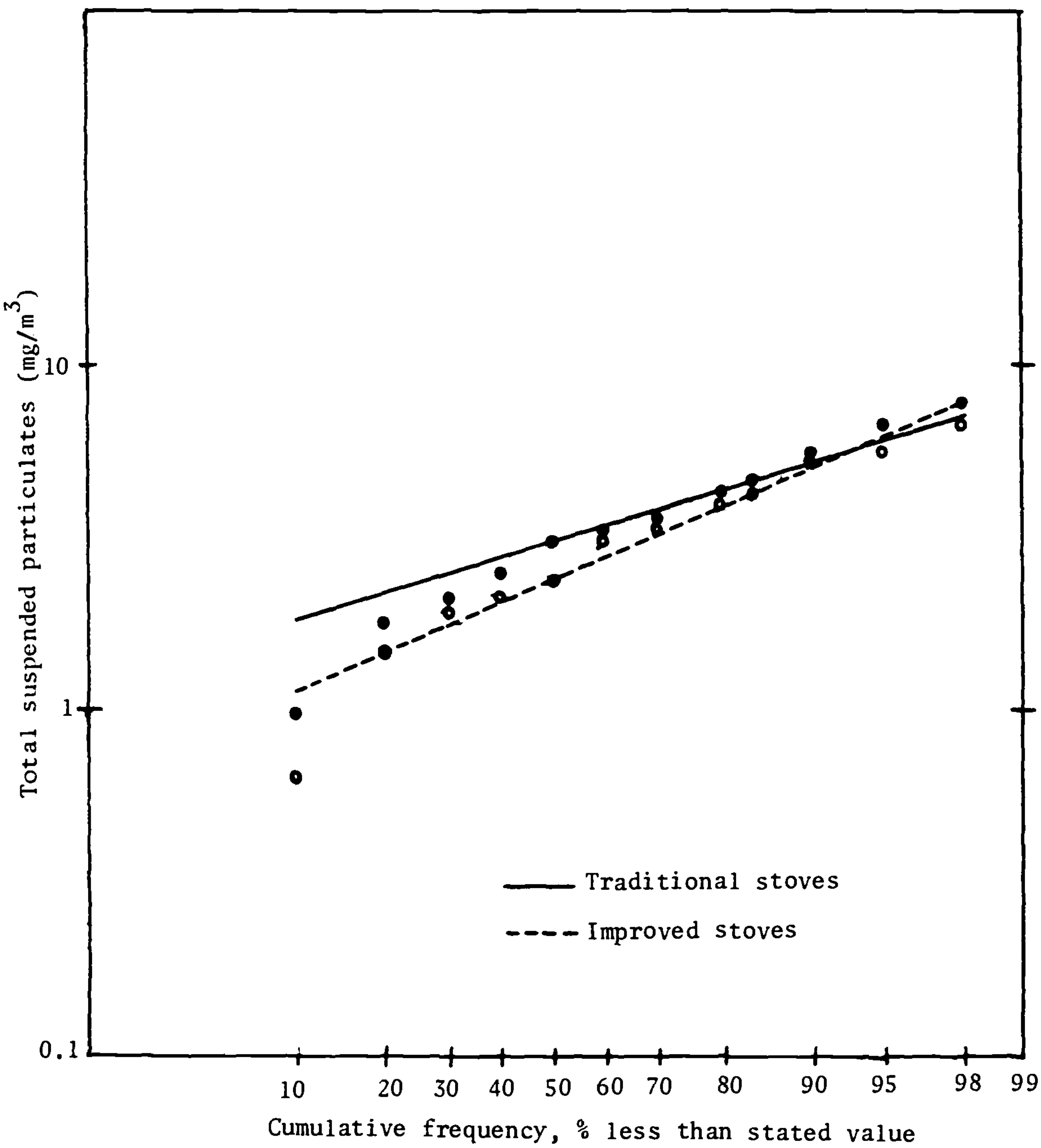

Figure 11. Total suspended particulate exposures in Garhibazidpur

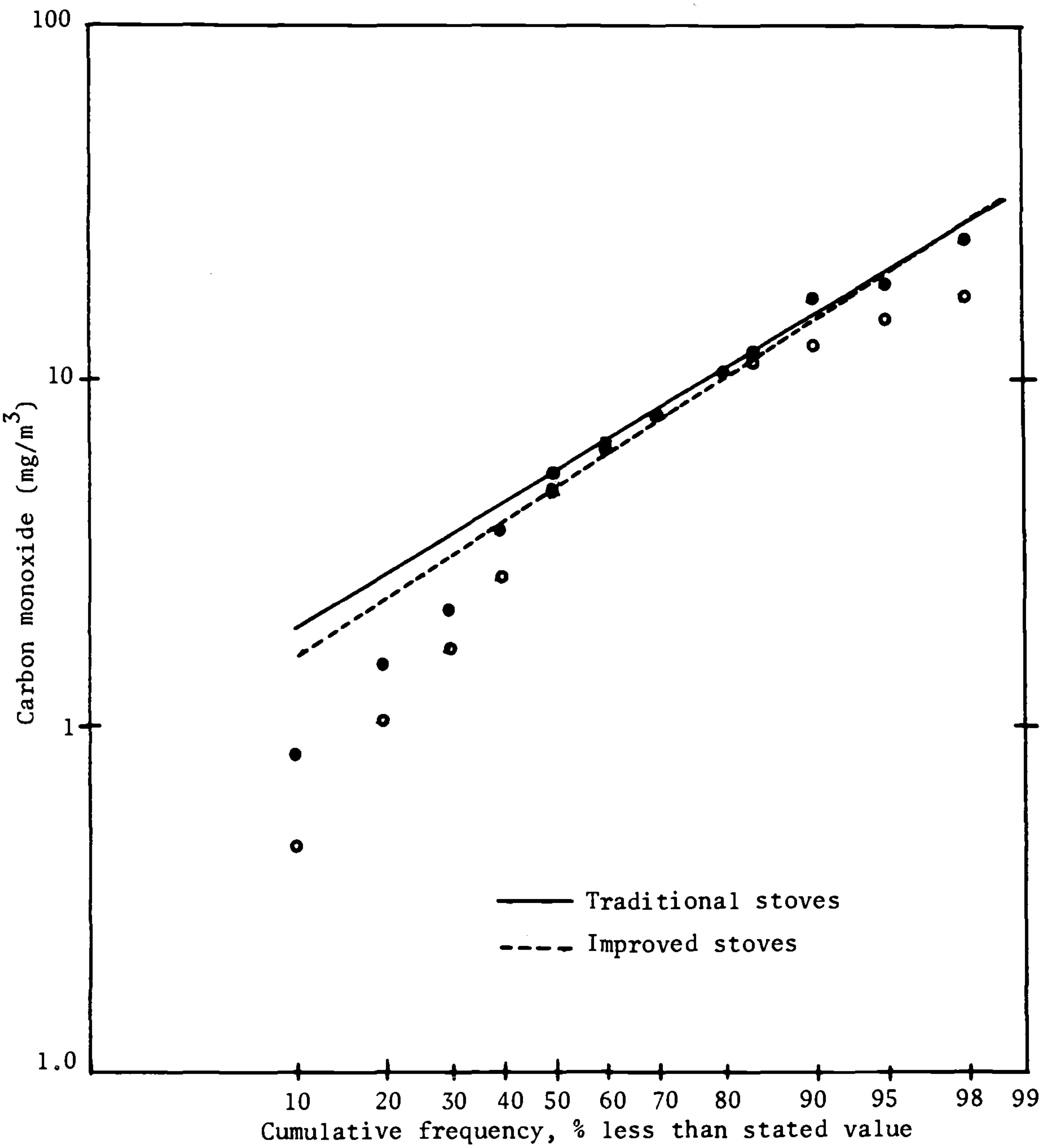

Figure 12. Carbon monoxide concentrations in Garhibazidpur

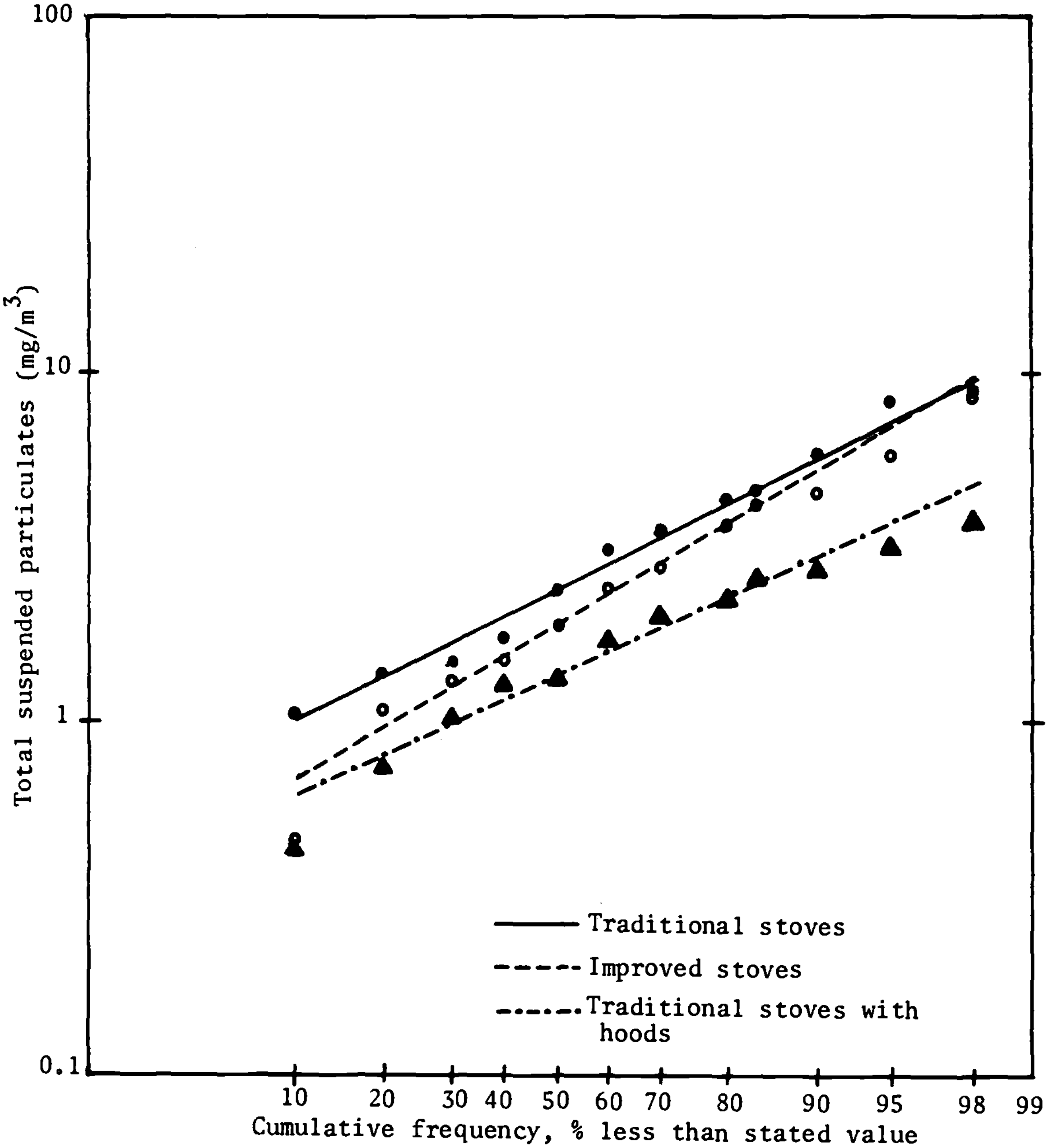

Figure 13. Total suspended particulate exposures in Keelara and Pallerayanahalli

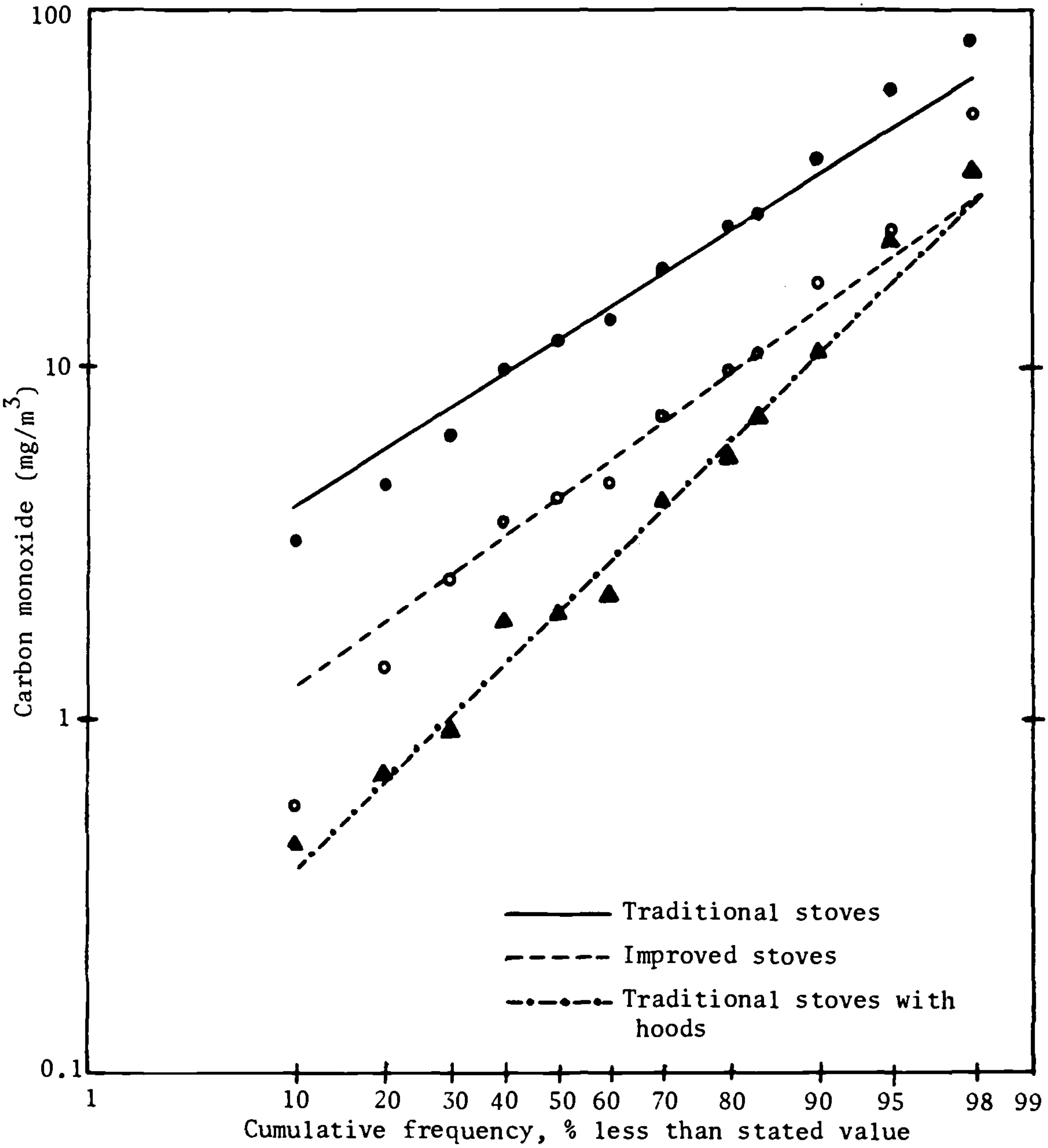

Figure 14. Carbon monoxide concentrations in Keelara and Pallerayanahalli

Table 24

General Model ANOVA for Garhibazidpur TSP data

Dependent variables : TESTTSP
Independent variables: CONstant CMAT KLOC STYPE KGPC KGHR FTYPE SEASON TEMP RH T
IME AMPM PMEAL
Number of cases is 87

Summary ANOVA Table Dependent Variable is TESTTSP

	DF	Sum-of-Squares	Mean-Square	F-Value	Prob	Rsq
Model	18	3.83	.21	.95	1	.20
Error	68	15.29	.22			
Corrected Total	86	19.12				

(Probabilities set to 1 when F or t-value is less than 1)

Dependent Variable is TESTTSP
SOURCE ordered

	Df	Sum-of-Squares-1	F-Value	Prob	Rsq	Adj-Rsq
CMAT	2	.41	.92	1.00	.02	.00
KLOC	2	.13	.28	1.00	.01	.00
STYPE	1	.50	2.24	.14	.03	.00
KGPC	1	.02	.07	1.00	.00	.00
KGHR	1	.05	.23	1.00	.00	.00
FTYPE	3	.41	.61	1.00	.02	.00
SEASON	2	1.62	3.61	.03	.08	.00
TEMP	1	.04	.17	1.00	.00	.00
RH	1	.13	.58	1.00	.01	.00
TIME	1	.23	1.03	.31	.01	.00
AMPM	2	.27	.60	1.00	.01	.00
PMEAL	1	.01	.06	1.00	.00	.00

(Probabilities set to 1 when F or t-value is less than 1)

SOURCE simultaneous

	Df	Sum-of-Squares-3	F-Value	Prob	Rsq	Adj-Rsq
CMAT	2	.00	.00	1.00	.00	.00
KLOC	2	.00	.00	1.00	.00	.00
STYPE	1	.43	1.89	.17	.02	.00
KGPC	1	.02	.10	1.00	.00	.00
KGHR	1	.03	.13	1.00	.00	.00
FTYPE	3	.20	.29	1.00	.01	.00
SEASON	2	.12	.27	1.00	.01	.00
TEMP	1	.00	.00	1.00	.00	.00
RH	1	.13	.56	1.00	.01	.00
TIME	1	.04	.20	1.00	.00	.00
AMPM	2	.23	.51	1.00	.01	.00
PMEAL	1	.01	.06	1.00	.00	.00

(Probabilities set to 1 when F or t-value is less than 1)

Table 24 (continued)

General Model ANOVA for Garhibazidpur TSP data

PARAMETER simultaneous

	b	Sum-of-Squares	F-Value	Prob
CONstant0	1.28	1.08	4.82	.03
CMAT1	-.17	.00	.00	1.00
CMAT2	.04	.00	.00	1.00
CMAT3	.00	.00	.00	1.00
KLOC1	.13	.00	.00	1.00
KLOC2	.00	.00	.00	1.00
KLOC3	.00	.00	.00	1.00
STYPE1	.16	.43	1.89	.17
STYPE2	.00	.00	.00	1.00
KGPC0	-.41	.02	.10	1.00
KGHR0	.08	.03	.13	1.00
FTYPE1	-.09	.06	.26	1.00
FTYPE2	-.13	.12	.52	1.00
FTYPE3	.06	.02	.11	1.00
FTYPE4	.00	.00	.00	1.00
SEASON1	.18	.04	.16	1.00
SEASON2	-.23	.09	.38	1.00
SEASON3	.00	.00	.00	1.00
TEMP0	.00	.00	.00	1.00
RH0	.00	.13	.56	1.00
TIME0	.00	.04	.20	1.00
AMPM1	-.01	.00	.00	1.00
AMPM2	.22	.23	1.03	.31
AMPM3	.00	.00	.00	1.00
PMEAL0	.01	.01	.06	1.00

(Probabilities set to 1 when F or t-value is less than 1)

Notes: CMAT = kitchen construction material
KLOC = kitchen location
STYPE = stove type
KGPC = fuel use per capita
KGHR = fueling rate (kg/hr)
FTYPE = fuel type
SEASON = time of year
TEMP = temperature
RH = relative humidity
TIME = length of cooking period
AMPM = time of day
PEMAL = number of persons at meal

Table 25

General Model ANOVA for Garhibazidpur CO data

Dependent variables : TESTCO
Independent variables: CONstant CMAT KLOC STYPE KGPC KGHR FTYPE SEASON TEMP RH TIME AMPM PMEAL
Number of cases is 87

Summary ANOVA Table Dependent Variable is TESTCO

	DF	Sum-of-Squares	Mean-Square	F-Value	Prob	Rsq
Model	18	21.37	1.19	2.07	.02	.35
Error	68	38.98	.57			
Corrected Total	86	60.36				

Dependent Variable is TESTCO
SOURCE ordered

	Df	Sum-of-Squares-1	F-Value	Prob	Rsq	Adj-Rsq
CMAT	2	1.71	1.49	.23	.03	.00
KLOC	2	4.43	3.86	.03	.07	.00
STYPE	1	1.32	2.29	.13	.02	.00
KGPC	1	.92	1.60	.21	.02	.00
KGHR	1	.67	1.17	.28	.01	.00
FTYPE	3	.23	.13	1.00	.00	.00
SEASON	2	3.95	3.44	.04	.07	.00
TEMP	1	4.16	7.26	.01	.07	.00
RH	1	.91	1.58	.21	.02	.00
TIME	1	.96	1.67	.20	.02	.00
AMPM	2	2.03	1.77	.18	.03	.00
PMEAL	1	.09	.16	1.00	.00	.00

(Probabilities set to 1 when F or t-value is less than 1)

SOURCE simultaneous

	Df	Sum-of-Squares-3	F-Value	Prob	Rsq	Adj-Rsq
CMAT	2	.00	.00	1.00	.00	.00
KLOC	2	.00	.00	1.00	.00	.00
STYPE	1	3.61	6.29	.01	.06	.00
KGPC	1	.10	.17	1.00	.00	.00
KGHR	1	.04	.08	1.00	.00	.00
FTYPE	3	.18	.11	1.00	.00	.00
SEASON	2	2.07	1.81	.17	.03	.00
TEMP	1	2.07	3.61	.06	.03	.00
RH	1	.87	1.52	.22	.01	.00
TIME	1	.75	1.31	.26	.01	.00
AMPM	2	2.04	1.78	.18	.03	.00
PMEAL	1	.09	.16	1.00	.00	.00

(Probabilities set to 1 when F or t-value is less than 1)

Table 25 (continued)

General Model ANOVA for Garhibazidpur CO data

PARAMETER simultaneous

	b	Sum-of-Squares	F-Value	Prob
CONstant0	-.67	.29	.51	1.00
CMAT1	4.60	.00	.00	1.00
CMAT2	5.02	.00	.00	1.00
CMAT3	.00	.00	.00	1.00
KLOC1	-4.40	.00	.00	1.00
KLOC2	-5.11	.00	.00	1.00
KLOC3	.00	.00	.00	1.00
STYPE1	.48	3.61	6.29	.01
STYPE2	.00	.00	.00	1.00
KGPC0	.88	.10	.17	1.00
KGHR0	-.10	.04	.08	1.00
FTYPE1	-.03	.01	.01	1.00
FTYPE2	.05	.02	.03	1.00
FTYPE3	.16	.15	.27	1.00
FTYPE4	.00	.00	.00	1.00
SEASON1	.08	.01	.01	1.00
SEASON2	-1.11	2.07	3.60	.06
SEASON3	.00	.00	.00	1.00
TEMP0	.06	2.07	3.61	.06
RH0	.01	.87	1.52	.22
TIME0	.01	.75	1.31	.26
AMPM1	.03	.01	.01	1.00
AMPM2	.65	2.04	3.55	.06
AMPM3	.00	.00	.00	1.00
PMEAL0	-.03	.09	.16	1.00

(Probabilities set to 1 when F or t-value is less than 1)

NOTES: CMAT = kitchen construction material
KLOC = kitchen location
STYPE = stove type
KGPC = fuel use per capita
KGHR = fueling rate (kg/hr)
FTYPE = fuel type
SEASON = time of year
TEMP = temperature
RH = relative humidity
TIME = length of cooking period
AMPM = time of day
PMEAL = number of persons at meal

Significant factors are underscored.

Table 26

General Model ANOVA for Keelara and Pallerayanahalli TSP data

Dependent variables : LNTSP
Independent variables: CONstant RTYPE STYPE KGPC KGHR FTYPE SEASON TEMP RH TIME AMPM PMEAL

Number of cases is 100

Summary ANOVA Table Dependent Variable is LNTSP

	DF	Sum-of-Squares	Mean-Square	F-Value	Prob	Rsq
Model	16	16.04	1.00	4.04	.00	.44
Error	83	20.60	.25			
Corrected Total	99	36.64				

Dependent Variable is LNTSP
SOURCE ordered

	Df	Sum-of-Squares-1	F-Value	Prob	Rsq	Adj-Rsq
RTYPE	2	1.73	3.48	.04	.05	.00
STYPE	2	4.10	8.25	.00	.11	.00
KGPC	1	.37	1.48	.23	.01	.00
KGHR	1	1.20	4.84	.03	.03	.00
FTYPE	3	.72	.96	1.00	.02	.00
SEASON	2	4.91	9.90	.00	.13	.00
TEMP	1	2.27	9.14	.00	.06	.00
RH	1	.05	.22	1.00	.00	.00
TIME	1	.67	2.70	.10	.02	.00
AMPM	1	.02	.06	1.00	.00	.00
PMEAL	1	.00	.00	1.00	.00	.00

(Probabilities set to 1 when F or t-value is less than 1)

SOURCE simultaneous

	Df	Sum-of-Squares-3	F-Value	Prob	Rsq	Adj-Rsq
RTYPE	2	1.81	3.64	.03	.05	.00
STYPE	2	5.89	11.86	.00	.16	.00
KGPC	1	.03	.10	1.00	.00	.00
KGHR	1	.20	.82	1.00	.01	.00
FTYPE	3	.71	.95	1.00	.02	.00
SEASON	2	2.35	4.73	.01	.06	.00
TEMP	1	1.10	4.43	.04	.03	.00
RH	1	.00	.01	1.00	.00	.00
TIME	1	.24	.98	1.00	.01	.00
AMPM	1	.01	.06	1.00	.00	.00
PMEAL	1	.00	.00	1.00	.00	.00

(Probabilities set to 1 when F or t-value is less than 1)

Table 26 (continued)

General Model ANOVA for Keelara and Pallerayanahalli TSP data

PARAMETER simultaneous

	b	Sum-of-Squares	F-Value	Prob
CONstant0	-2.17	.62	2.49	.12
RTYPE1	.15	.26	1.06	.31
RTYPE2	.38	1.54	6.21	.01
RTYPE3	.00	.00	.00	1.00
STYPE1	.36	1.43	5.75	.02
STYPE2	.60	4.46	17.97	.00
STYPE3	.00	.00	.00	1.00
KGPC0	-.21	.03	.10	1.00
KGHR0	.14	.20	.82	1.00
FTYPE1	-.09	.08	.34	1.00
FTYPE2	.41	.54	2.18	.14
FTYPE3	-.09	.08	.32	1.00
FTYPE4	.00	.00	.00	1.00
SEASON1	-.49	1.35	5.44	.02
SEASON2	-.35	1.00	4.02	.05
SEASON3	.00	.00	.00	1.00
TEMP0	.09	1.10	4.43	.04
RH0	.00	.00	.01	1.00
TIME0	.00	.24	.98	1.00
AMPM1	.05	.01	.06	1.00
AMPM2	.00	.00	.00	1.00
PMEAL0	.00	.00	.00	1.00

(Probabilities set to 1 when F or t-value is less than 1)

Notes: RTYPE = roof type
STYPE = stove type
KGPC = fuel use per capita
KGHR = fueling rate (kg/hr)
FTYPE = fuel type
SEASON = time of year
TEMP = temperature
RH = relative humidity
TIME = length of cooking period
AMPM = time of day
PMEAL = number of people at meal

Significant factors are underscored.

Table 27

General Model ANOVA for Keelara and Pallerayanahalli CO data

Dependent variables : LNCO
Independent variables: CONstant RTYPE STYPE KGPC KGHR FTYPE SEASON TEMP RH TIME AMPM PMEAL
Number of cases is 100

Summary ANOVA Table Dependent Variable is LNCO

	DF	Sum-of-Squares	Mean-Square	F-Value	Prob	Rsq
Model	16	88.83	5.55	9.50	.00	.65
Error	83	48.49	.58			
Corrected Total	99	137.32				

Dependent Variable is LNCO
SOURCE ordered

	Df	Sum-of-Squares-1	F-Value	Prob	Rsq	Adj-Rsq
RTYPE	2	10.57	9.05	.00	.08	.00
STYPE	2	32.27	27.62	.00	.23	.09
KGPC	1	.82	1.40	.24	.01	.00
KGHR	1	7.03	12.03	.00	.05	.00
FTYPE	3	2.10	1.20	.32	.02	.00
SEASON	2	9.66	8.26	.00	.07	.00
TEMP	1	25.38	43.44	.00	.18	.03
RH	1	.04	.06	1.00	.00	.00
TIME	1	.08	.13	1.00	.00	.00
AMPM	1	.48	.83	1.00	.00	.00
PMEAL	1	.41	.71	1.00	.00	.00

(Probabilities set to 1 when F or t-value is less than 1)

SOURCE simultaneous

	Df	Sum-of-Squares-3	F-Value	Prob	Rsq	Adj-Rsq
RTYPE	2	8.42	7.21	.00	.06	.00
STYPE	2	33.99	29.09	.00	.25	.10
KGPC	1	.07	.13	1.00	.00	.00
KGHR	1	.79	1.36	.25	.01	.00
FTYPE	3	2.79	1.59	.20	.02	.00
SEASON	2	1.94	1.66	.20	.01	.00
TEMP	1	9.02	15.44	.00	.07	.00
RH	1	.17	.29	1.00	.00	.00
TIME	1	.46	.79	1.00	.00	.00
AMPM	1	.30	.51	1.00	.00	.00
PMEAL	1	.41	.71	1.00	.00	.00

(Probabilities set to 1 when F or t-value is less than 1)

Table 27 (continued)

General Model ANOVA for Keelara and Pallerayanahalli CO data

PARAMETER simultaneous

	b	Sum-of-Squares	F-Value	Prob
CONstant0	-5.89	4.54	7.77	.01
RTYPE1	.27	.85	1.46	.23
<u>RTYPE2</u>	<u>.84</u>	<u>7.57</u>	<u>12.96</u>	<u>.00</u>
RTYPE3	.00	.00	.00	1.00
<u>STYPE1</u>	<u>.70</u>	<u>5.29</u>	<u>9.06</u>	<u>.00</u>
<u>STYPE2</u>	<u>1.52</u>	<u>28.70</u>	<u>49.13</u>	<u>.00</u>
STYPE3	.00	.00	.00	1.00
KGPC0	-.36	.07	.13	1.00
KGHR0	.27	.79	1.36	.25
FTYPE1	-.27	.71	1.21	.27
FTYPE2	.73	1.68	2.88	.09
FTYPE3	-.21	.40	.68	1.00
FTYPE4	.00	.00	.00	1.00
SEASON1	.19	.21	.36	1.00
SEASON2	-.45	1.73	2.95	.09
SEASON3	.00	.00	.00	1.00
<u>TEMP0</u>	<u>.25</u>	<u>9.02</u>	<u>15.44</u>	<u>.00</u>
RH0	-.01	.17	.29	1.00
TIME0	.01	.46	.79	1.00
AMPM1	.23	.30	.51	1.00
AMPM2	.00	.00	.00	1.00
PMEAL0	-.07	.41	.71	1.00

(Probabilities set to 1 when F or t-value is less than 1)

Notes: RTYPE = roof type
STYPE = stove type
KGPC = fuel use per capita
KGHR = fueling rate (kg/hr)
FTYPE = fuel type
SEASON = time of year
TEMP = temperature
RH = relative humidity
TIME = length of cooking period
AMPM = time of day
PMEAL = number of people at meal

Significant factors are underscored.

Table 28. Summary of T-test Results on Air Pollution Data

Variable	Pollutant	Finding	p
Stove type	TSP	Exposures higher with unmodified traditional stoves than with traditional stoves w/hoods	P<0.001
	CO	Concentrations higher with unmodified traditional stoves than with traditional stoves w/hoods	P<0.001
Roof type	TSP	Higher exposures in kitchens with mud roof than in tile roofed kitchens	P<0.04
	CO	Higher concentrations in kitchens with mud roofs than in tile roofed kitchens	P<0.01
Kitchen location	CO	Higher concentrations in indoor kitchens than in protected kitchens	P<0.01
	CO	Higher concentrations in indoor kitchens than in outdoor kitchens	P<0.03

significantly higher in indoor kitchens than in protected kitchens (P<0.01) or in outdoor kitchens (P<0.03).

In the southern villages, statistically significant differences in exposures and concentrations based on stove type and roof type were detected. The difference in exposure between the traditional stove and the improved stove was not statistically significant but there was a reduction by a factor of 1.3; the reduction in CO concentration was more dramatic (a factor of 2.7) and was statistically significant (P<0.001). A point worthy of note is that lower TSP exposures and CO concentrations were found in southern homes using traditional cookstoves placed under fireplace-like hoods (TSP exposures decreased by a factor of 1.8 and CO concentrations by a factor of 4.3) compared to homes where traditional stoves were being used. These differences were statistically significant (P<0.001 for CO as well as TSP). A similar reduction in TSP exposures was not detectable when comparing homes using the improved stove and the traditional cookstove, though there was a significant decrease in CO concentrations. The CO data support what the TSP data show except that the reduction in CO concentrations in households in the south where new stoves are in use is more pronounced. The reason for this is not clear but may be related to the problems of using stationary monitors in field situations. TSP exposures and

Table 29. Specific Fuel Consumption of Keelara and Pallerayanahalli Stoves

Stove type	Persons cooked for (n)	Cooking time (min)	Burn rate (kg/hr)	Fuel use (kg/pc)	Specific fuel consumption (kg/kg)
ASTRA (n = 40)					
Mean	6.1	58	2.05	0.37	0.365
Standard deviation	2.2	15	0.53	0.17	0.146
Coefficient of variation	0.36	0.26	0.26	0.47	0.4
Traditional (n = 39)					
Mean	5.7	59	1.94	0.38	0.345
Standard deviation	2.3	19	0.49	0.20	0.099
Coefficient of variation	0.41	0.33	0.25	0.53	0.29
Traditional w/hood (n = 24)					
Mean	6.4	68	1.98	0.38	0.362
Standard deviation	2.4	25	0.52	0.183	0.121
Coefficient of variation	0.38	0.37	0.26	0.48	0.33

CO concentrations were higher in mud-roofed houses than in tile-roofed houses ($P<0.04$, $P<0.01$) and also in thatch houses but here the difference is not statistically significant. The average CO levels were higher in the south largely because of limited ventilation in the kitchens of older houses. This problem might resolve itself as the older houses are replaced by new constructions that allow light and air to enter the kitchen.

The ANOVA on the TSP data from the southern villages showed "season" to be an important factor, a finding that was rather inexplicable since there was in fact very little climatic variation during the measurement periods: the monsoon failed in both study sites that year so that though relative humidity increased during the second measurement period, no rain actually fell during measurement sessions. The "seasonal" variations normally seen such as changes in moisture content of fuel, in fuels used, in cooking schedule, and so on were were either absent or less marked. In any case, the ANOVA did not reveal relative humidity and fuel type as being critical in explaining variance in the data. A further check was done by conducting a Wilcoxon signed-ranks test on data from households for which "true" replicates existed, that is, houses in which there was no change in stove type or cook between measurement periods. The results show that there are no significant seasonal variations in TSP exposures.

Another factor that appears influential based on the results of the ANOVA for the southern villages was temperature in the cooking area at the beginning of cooking which coincided with the start of the measurement period. A positive correlation exists between temperature and TSP exposures (0.40) and between temperature and CO concentrations (0.53). The change in both TSP and CO per unit change in temperature seems to be small. In all the villages, TSP exposures and CO concentrations were positively correlated though this association was stronger in the southern villages (0.64) than in Garhibazidpur (0.30).

The efficiency of the improved cookstove in the southern villages was determined using specific fuel consumption (SFC) as a measure. SFC is expressed as the units of fuel burned per unit of cooked food. The SFC of the three stove types was quite similar (Table 29) and no correlation appeared to exist between exposures and SFC.

A brief digression may be in order here to discuss the role and measurement of efficiency in the evaluation of cookstove performance. There exists an established international protocol for testing cookstove efficiency (VITA, 1985) agreed upon after intensive experimentation and discussion among the various groups involved in improved cookstove design. The most commonly used measure is the water-boiling test where the length of time and the weight of fuel required to bring a given quantity of water to a boil is recorded. The strengths of the test are its reproducibility and comparability. The main disadvantage is that it does not, in most cases, mimic the cooking process very well and hence may not be a realistic measure. SFC, on the other hand, measures the performance of the stove during the actual cooking process. It is not, however, readily reproducible or comparable. Additional reservations about SFC include the fact that it does not distinguish between different types of food and also does not account for the number of dishes cooked. The SFC data in Table 29, then, should be viewed with these limitations in mind.

Results of Survey

The survey results were cross-tabulated. The baseline data on types of stove used, fuel use patterns, and cooking practices were reported in Chapter 2. The remaining part of the survey focused on fuel use preferences, perceptions of domestic air pollution, and on evaluation of the improved cooking stoves. The questions were similarly worded in Garhibazidpur and in the southern villages. Tables 30 and 31 summarize the responses to the queries on fuel use preferences in the north and the south. Women were asked to select from among the fuels they commonly use the ones that they consider to be the smokiest, the least smoky, the quickest in completing the task, and the slowest. It is interesting to note that in Garhibazidpur the majority of the women identified a particular type of fuel when responding. There was overwhelming agreement that keekar (Acacia nilotica) is the least smoky and quickest cooking fuel. The slowest fuel category had the greatest diversity of answers but the general response of "crop residues" formed the largest group (36%). In the southern villages, women normally associated a fuel characteristic with smokiness, non-smokiness, etc., rather than a particular type of fuel. For example, almost half of the women said that wet or fresh wood is the smokiest fuel, and about 40 percent indicated that large pieces of wood would be the least smoky. This difference in responses between Garhibazidpur and the southern villages may be because cooking fuels are burned singly more frequently (52 percent) in the former than in the latter (24 percent) providing

Table 30. Perceptions of Fuel Quality in Garhibazidpur

Type of fuel	Most smokey		Least smokey		Quickest		Slowest	
	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)
Guar	25	40					12	19
Dung	14	23					10	16
Aakhada	8	13					3	5
Crop residues	7	11					22	36
Keekar			59	95	56	90		
Sarson	5	8					8	13
Large pieces					3	5		
Other	4	5	3	5	3	5	7	11

Note: n = 62; Guar, Cymopsis tetragonoloba; Aakhada, Calotropis procera; Keekar, Acacia nilotica; Sarson, mustard

Table 31. Perceptions of Fuel Quality in Keelara and Pallerayanahalli

Type of fuel	Most smokey		Least smokey		Quickest		Slowest	
	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)
Wet/fresh wood	46	46					20	21
Twigs	23	23					41	43
Aala	19	19					8	8
Coconut wastes	18	18					17	18
Dung	11	11						
Large pieces			39	39	30	30		
Dry wood			32	32	17	17		
Gobli			16	16	29	29		
Cut wood			14	14	10	10		
Bevu			13	13	12	12		
Hongay			12	12				
Hippay					12	12		
Basri							6	6
Don't know	5	5	8	8	8	8	10	11
No response	4	4	4	4	3	3	4	4
Total number of respondents	100		100		99		95	

Note: Many multiple responses were received so the column totals and percentages do not add up perfectly. Aala, Ficus bengalensis; Gobli, Acacia nilotica; Bevu, Azadirachta indica; Hongay, Pongamia glabra; Hippay, Madhuka longifolia; Basri, Ficus retusa

Table 32. Perceptions of Smoke from Cookstoves in Garhibazidpur

Opinion	n	%
Smoke does not bother	8	13
Blackens pots	9	14
Blackens walls	15	24
Irritates eyes	47	76
Causes nose to run	7	11
Causes coughing	10	16
Causes headaches	5	8
Other	9	14
No response	3	5
Total number of respondents	62	

Note: Many multiple responses were received so the column totals and percentages do not add up perfectly.

more opportunities for Garhi women to observe the properties of particular types of fuel. A common feature of responses from all villages was that people generally identified the same fuel or fuel characteristic when naming the smokiest and the slowest fuel and, similarly, when selecting the least smoky and the quickest fuel.

Another set of questions related to whether the women viewed indoor air pollution as a problem, and if they did, whether they had taken any measures to alleviate it, and whether they saw any benefits to having smoke in the cooking area or household. The responses to these questions are summarized in Tables 32 and 33. In all the villages, more than two-thirds of the women associated eye irritation with smoky cooking stoves. In the southern villages, 45 percent also mentioned headaches resulting from exposure to indoor air pollution. This is in comparison to eight percent in Garhibazidpur where better-ventilated kitchens are more prevalent. Blackening of walls and cooking pots were other problems mentioned.

In Garhibazidpur, 17 percent felt indoor air pollution is not a problem while in the southern villages, 24 percent had this opinion. When asked if they had taken any steps to reduce indoor air pollution, 40 percent said they had tried the new stove, 35 percent replied in the negative, and 11 percent said they avoided smoky fuels. In the southern villages, a larger percentage said they had taken no ameliorative measures (52 percent). A further 20 percent each said they had either adopted the new stove or had a hood over their traditional stove. Though people are obviously aware of the relative smokiness of various fuels, in neither place did they appear to make conscious efforts to procure and use less smoky fuels. Finally, the majority of the people in Garhibazidpur said they could see no benefits to having smoke in the house (79 percent); this reaction was less

Table 33. Perceptions of Smoke from Cookstoves in Keelara and Pallerayanahalli

Opinion	n	%
Smoke does not bother	24	24
Blackens pots	13	13
Blackens walls	39	39
Irritates eyes	68	68
Causes nose to run	21	21
Causes coughing	17	17
Causes headaches	45	45
Other	1	1
Total number of respondents	100	

Note: Many multiple responses were received so the column totals and percentages do not add up perfectly.

overwhelming in the southern villages where a substantial percentage of people perceived the smoke as beneficial in repelling mosquitoes (39 percent) and preserving thatch from termites and other insects (28 percent).

A further series of questions tried to gather reactions to the improved cookstoves. These responses are shown in Tables 34 and 35. Only 65 percent of those whose opinions were surveyed in Garhibazidpur and 48 percent of those in southern villages had improved cookstoves; hence only their responses are included in these tables. The most striking differences between Garhibazidpur and the southern villages relate to the opposite estimations of stove performance. The only agreement is in the assessment by those using the improved cookstoves regularly that both stoves reduce the amount of smoke in the cooking area. Though the measurements of TSP exposure and CO concentrations indicate this not to be the case, these perceptions are of interest as they demonstrate once again the imprecision with which human senses detect environmental hazards. The other measures of performance which were included in the questionnaire — fuel consumption, cooking time, and health effects — although by no means free of the need for subjective judgement, are perhaps less prone to error in assessment. A further complication is the tendency for the expectations of the person conducting the survey to influence the responses elicited from people, inspite of efforts to avoid such bias. Perhaps the women sensing the interest in the smokiness of stoves tailor their replies accordingly whereas researcher bias for the other measures of performance may not have been as obvious.

Discussion

Though Keelara and Pallerayanahalli have repeatedly been referred to as the "southern villages" it is not the intention to imply that these findings are representative of the situation in south India. Nor is Garhibazidpur meant to be

Table 34. Evaluation of the Improved Cookstove in Garhibazidpur

	n	%
Frequency of use		
Always	7	17
Frequently	7	17
Sometimes	6	15
Never	20	50

Fuel consumption, smokiness, time requirement

	Fuel consumption		Smokiness		Time requirement	
	n	%	n	%	n	%
Less	3	7.5	15	38	5	12
Same	8	20	1	2.5	6	15
More	7	17	2	5	7	17
Not applicable	20	50	20	50	20	50
Don't know	2	1	2	1	2	1

Perceived impact on health

	n	%
No effect	12	60
Fewer colds	1	5
Eyes less irritated	6	30
Decreased coughing	1	5
Fewer headaches	1	5

Reasons for irregular use or disuse

Higher fuel consumption	8	31
Higher time requirement	2	8
Difficult to start fire	3	11
Smokier	4	15
Difficult to make rotis	6	23
Faulty construction	5	19
Inappropriate location	7	27
Disintegrated in monsoon	7	27
Demolished	7	27
Other	3	11
Haven't used	2	8

Note: n = 40, that is, 40 of the 62 households surveyed had the new stove. Many multiple responses were received so the column totals and percentages do not add up perfectly.

Table 35. Evaluation of the Improved Cookstove in Keelara and Pallerayanahalli

Frequency of use

	n	%
Always	37	77
Frequently	4	8
Sometimes	3	6
Never	3	6
No response	1	2

Fuel consumption, smokiness, time requirement

	Fuel consumption		Smokiness		Time requirement	
	n	%	n	%	n	%
Less	38	79	35	73	41	85
Same	5	10	6	12	3	6
More	0	0	3	6	0	0
Not applicable	3	6	3	6	3	6
No response	2	4	1	2	1	2

Perceived impact on health

	n	%
No effect	20	42
Eyes less irritated	22	46
Decreased coughing	6	12
Fewer headaches	11	23
Other	2	4

Note: n = 48, that is, 48 of the 100 households surveyed had the new stove. Many multiple responses were received so the column totals and percentages do not add up perfectly.

representative of north India. This is not a regional study of domestic air pollution. Cultural and environmental conditions vary too widely in north and south India for generalizations to be made on the basis of data collected in one or two villages. Comparisons and contrasts have been made between the two study sites as a means of highlighting findings rather than to draw conclusions for a larger geographic area. If anything, this field study has shown that the natural variability in air pollution data makes it extremely difficult to extrapolate from the specific to the general. These are, essentially, site-specific observations which may be applicable to somewhat larger geographic units than the villages themselves but certainly not to all of northern or southern India.

There was a readily observable contrast between the environment and culture of Garhibazidpur and the southern villages. Some of these differences are reflected in the picture of domestic air pollution that can be constructed from the data. The kitchens in the southern villages are located to maximize privacy and, unfortunately, this is often achieved at the expense of adequate ventilation. The higher CO concentrations observed in the south are probably related to this characteristic of cooking areas. In comparison, cooking areas in Garhibazidpur were sometimes open-air and almost always well-ventilated. Consequently, CO concentrations were lower. The effect of ventilation on TSP exposures is less easily quantified based on these field data.

Since cooking practices differ greatly between the study sites it was expected that some effect of this might be discernable in the measured exposures and concentrations. The basic process in preparing roti, the staple food of the north involves roasting it on a griddle and then exposing it to a radiant flame. Rice and ragi, the mainstays of the southern villages, require boiling. This difference in the cooking process determines not only the amount of time the cook spends near the stove but also her proximity to it. In Garhibazidpur, the cook needs access to the combustion chamber and remains by the stove till roti-making is completed. Ragi and rice preparation do not call for such close attention and the cook is able to take care of other household tasks while waiting for the pots to come to a boil. Based only on these differences, one might expect that Garhibazidpur cooks would receive larger TSP exposures. This, however, proved not to be the case. The average TSP exposures in both places were on the order of 2.6-3.1 mg/m3. The disruption caused by our presence may have overwhelmed the influence of cooking process on exposures. Besides ourselves, a group of neighbors and spectators often gathered in the kitchen. Also, other factors such as the size of fuel and the rapidity with which it burns might dictate the cook's movements, overriding the requirements of the cooking process.

The types of fuel used in the two study sites offered a contrast too -- specifically the greater use of dung in Garhibazidpur -- which were expected to lead to variations in exposures and concentrations. Since the type of fuel used was not controlled during the measurements (in order to preserve routine practices as far as possible) it was found that cooks often use a mix of various fuels -- including crop residues -- and it was difficult to separate the contribution of individual fuels. Even when fuel usage is aggregated into three broad categories, wood, crop residues, and dung, no apparent differences emerge. It appears that in the field where various types of fuel are being burned under rudimentary conditions, the differences in combustion and ventilation conditions may mask the effect of the specific fuels in use. Overall, then, there were not striking differences between exposures and concentrations in Garhibazidpur and the southern villages.

The TSP exposures and CO concentrations measured in this study are not radically different from previous measurements (Tables 3-6 in Chapter 1). The CO concentrations found are perhaps lower than those found previously but this may be partially due to the ample provisions for ventilation in many kitchens in Garhibazidpur especially in comparison with the southern kitchens and the kitchens investigated in other studies.

Within each village, the variation in exposures and concentrations is quite high. T-tests confirmed that some differences by stove type exist but the reduction brought about by improved cookstoves is not striking. There was no statistically significant difference by stove type in Garhibazidpur and in the southern villages the reductions in households using the traditional stove under a hood chimney were greater than in households using the newly introduced improved cookstove.

This indigenous response to the indoor air pollution problem appears to be an extremely effective method of removing smoke from the kitchen. The major advantage of the hood chimney is that it seems to be impervious to user idiosyncracies. An operator using a traditional stove under a well-built hood may do just about anything -- alter the burn rate or leave ports uncovered -- and have very little effect on the amount of smoke escaping into the kitchen. There is no need for the cook to modify her behavior or change the cooking process. In its present form the hood, massive and expensive, is available only to the more affluent rural population. The hoods cannot be accommodated in thatch dwellings and it is difficult to retrofit kitchens with them. The design principle of the hood is simple, however, and hoods could probably be incorporated into any new government-subsidized housing. In addition, the hoods could be constructed of some cheaper, light-weight material making them affordable to a larger section of the population. A feasible alternative, especially in the north where a seasonal shift in kitchen location is customary, maybe the combination of a portable improved (metal) cookstove and a light-weight hood.

The reductions in CO concentrations in homes with the new stoves was more marked than the reductions in TSP exposures. The reasons for this discrepancy is not entirely clear. Since personal monitoring of CO was not conducted, the possibility that there were shifts of the ratio of CO/TSP emissions cannot be discounted. Also, the TSP monitors did not distinguish among particles of various sizes so, possibly, changes in the background dust levels affected the measurements.

There are many possible reasons for the mixed performance of improved cookstoves. A contributing factor may be the relatively frequent occurrence of ground-level temperature inversions in north India. The mean ambient TSP concentration in Garhibazidpur was 1.1 mg/m3 compared to a mean concentration of 0.15 mg/m3 in the southern villages. Where inversions exist, a significant portion of the smoke escaping from flues may reenter the cooking area (Smith, 1987b). There is little doubt that smoke from the stoves is resulting in elevated ambient TSP concentrations. Smith and Durgaprasad (1987) did an air pollution "transect" of one of their study villages. One of the authors walked from the center of the village to the surrounding fields holding a Miniram TSP monitor (infrared scattering) recording concentration every five paces. The resulting transect showed relatively high ambient TSP levels and a sharp transition at the village boundary. A similar transect was done in Garhibazidpur (Figure 15) except it ran from one end of the village to the other. Again, there is a sharp decrease in levels at the village perimeter but there are also lower concentrations at the village center. Perhaps this is because there are several community activity buildings located in that area and the housing density is lower.

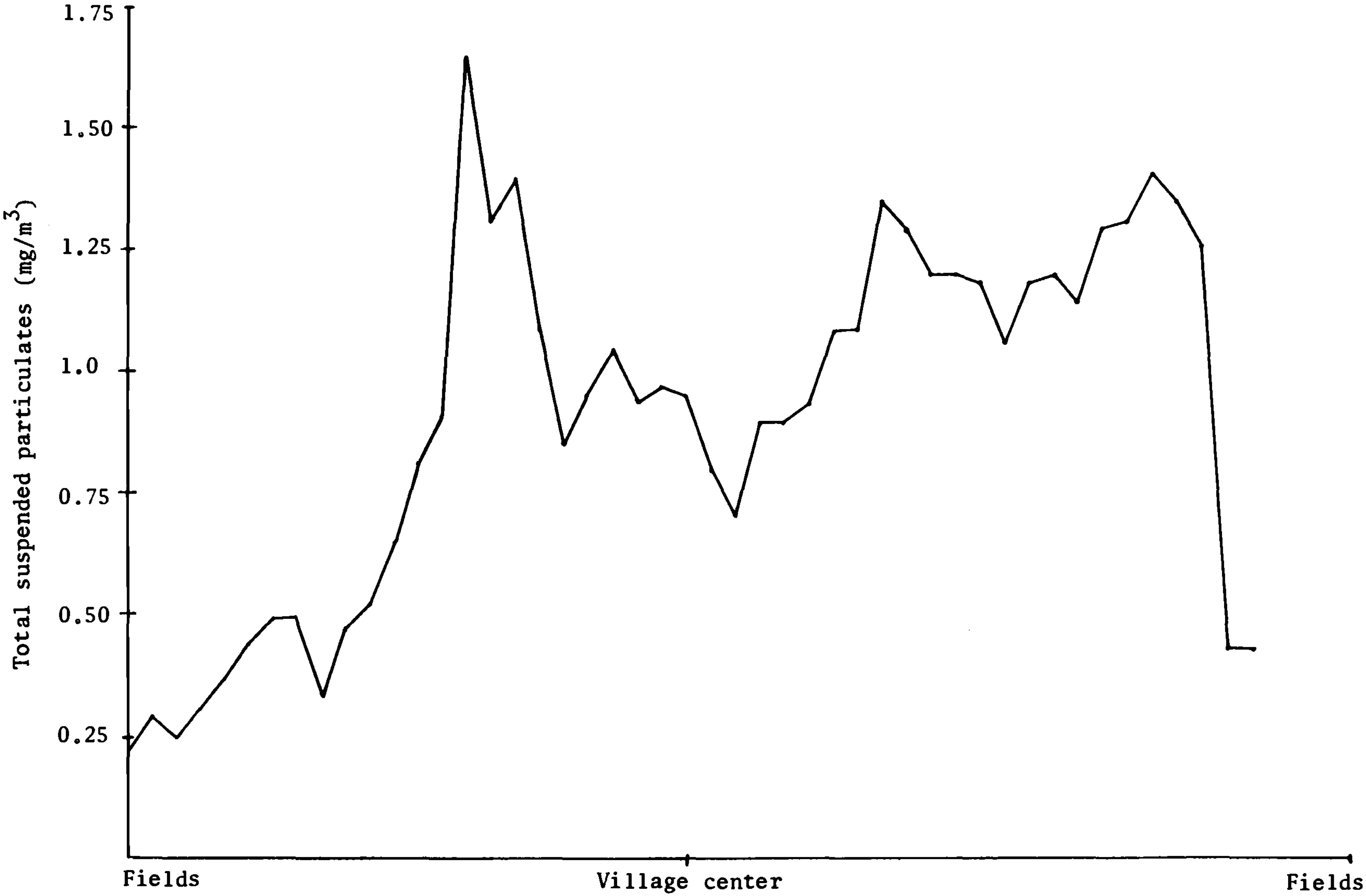

Figure 15. Ambient TSP concentrations in Garhibazidpur--A village transect

In any case, the fact remains that the improved cookstoves investigated in the study were not significantly better than traditional stoves in terms of TSP exposures and CO concentrations. The relatively poor performance of improved stoves in reducing exposures raises another issue: are improved smokeless stoves realistic longterm solutions to high TSP and CO exposures? Even the traditional stove under a hood does not bring exposures to within the levels stipulated by the Indian ambient air quality standards (0.1-0.5 mg/m3) although these are based on longer averaging times. This will discussed further in the next chapter.

Apart from stove type, the kitchen location, roof type, and temperature were also found to play a role and their effect has already been discussed. Factors that were expected to have an effect on TSP exposures and CO concentrations and proved not to were kitchen construction material, burn rate, length of cooking period, time of meal preparation, inter alia. It should be emphasized that the lack of association may be related to the characteristics of this data set and should not be interpreted as an absence of relationship.

A variable that needs to be examined further is operator behavior. It seems reasonable to assume that the cook will attempt to reduce smokiness as far as possible but this should not be taken for granted. She may well have other priorities such as reducing cooking time or minimizing fuel consumption (Sarin, 1987b). Her perception of smokiness may not be an accurate measure of the hazard. The pollutants that human senses are able to detect are not necessarily the ones most harmful to human health. Humans react relatively quickly to TSP and formaldehyde but the same is not true of CO, for example. This points to the need for field measurements of both exposures and perceptions in order to determine the seriousness of the hazard, to gauge people's willingness to reduce it, and to obtain a sense of their priorities.

The survey showed that people do indeed perceive domestic air pollution to be a problem and that some had experimented with the improved cookstove in the hope that it would be an effective means of eliminating the smoke. This is in keeping with the findings of earlier surveys (Bajracharya, 1983; Joseph, 1987; Sarin, 1987b) which found that people often place more importance on reducing indoor smoke concentrations and exposures than on improved efficiency and their reasons for adopting the stove may have more to do with the former than the latter. Fuel scarcity in most of south Asia is not as acute as it is in much of Africa. Though people may be travelling longer distances to collect their cooking fuel and though they may be forced to substitute crop residues or dung for wood, they are generally still not in the desperate situation where a major portion of each day must be spent in searching for cooking fuel. In addition, in the study areas, at least, the majority of the people continue to gather fuel rather than buy it. Hence, efficiency and conservation are frequently not the major concerns.

The survey also showed that though people might think that smoke from the cookstove is a problem, the majority have not taken any active measures to change the situation. This is indicative not only of people's priorities but also perhaps of the decision-making structure within the household where though the kitchen is unarguably the woman's domain, actions that involve substantial expenditure usually require the consent of the male head of household. Neither of the study sites had matriarchal societies: it would, incidentally, be intriguing to examine the situation in places where such a system is followed.

The difficulty in arriving at a quantitative estimate of the influence of the various cultural and environmental factors on TSP exposures and CO concentrations could be explained in several ways. The natural variability of the data probably accounts for it at least in part. It is also possible that cooks work to achieve a minimum level of comfort and do so by manipulating some of these same factors. This could be tested by focusing on operator behavior, breaking it down into manageable components, when taking measurements of pollution levels.

Regardless of these issues, the data show quite clearly the relative performance of the traditional and improved cookstoves. It is also apparent that in the field the new stoves do not show as much improvement as expected. Their present performance and possible future role is discussed in the context of dissemination programs in the next chapter.

Chapter 5

IMPLICATIONS FOR IMPROVED COOKSTOVE PROGRAMS: DISSEMINATION IN AN UNEQUAL WORLD

The field data show that the performance of the improved cookstove in terms of decreasing domestic air pollution was not vastly superior to that of the traditional stove and, in the case of Garhibazidpur, the improvement was not statistically significant. There could be several reasons for this. The first consideration is a technical defect in stove design but this is improbable since both stoves were tested rigorously in the laboratory (Lokras et al., 1983; Jindal and Prasad, 1987). A second possibility which is explored here relates to the characteristics of the dissemination programs. A recent study of adoption of smokeless woodstoves in Rajasthan found that dissemination program policies rather than the acceptor's personal characteristics were critical in attaining a high level of acceptance (Fraser, 1987). It appears that the importances of designing dissemination programs carefully cannot be overemphasized.

Dissemination Summarized

Improved cookstove programs are not new to the rural Indian landscape. They were promoted in the 1950s by Gandhian and other voluntary organizations working to improve the general quality of life in villages and later by various government agencies and private groups interested in alleviating health problems and fuel scarcity (Raju, 1953; HERL, 1968). The relationships between cookstoves and health, and cookstoves and deforestation were not investigated systematically. It was assumed that an improved cookstove would improve the health of rural women, ease fuel scarcity, and curb deforestation. Many dissemination strategies were attempted with varying degrees of success. At first these efforts were not well-documented and it is impossible to estimate how many improved cookstove programs came and went. Of late, though, there has been a spate of surveys, reports, discussions, and evaluations of improved cookstove dissemination programs (Foley and Moss, 1983; Maniboq, 1984; Agarwal, 1986; Joseph, 1987; FWD, 1987) in India and elsewhere. Several conclusions emerge from this literature, the principal ones being

* **Improved cookstove technology is not as simple as it might appear, and its complexity arises largely from the social and cultural context within which it operates.**

  - an understanding of this context is crucial to organizing an effective dissemination program.

- a program that ignores these realities cannot achieve its goals or sustain changes that it generates. These often site-specific social and cultural conditions are as critical as the design of the stove or the technical aspects of the program.

* **An effort must be made to integrate the innovation and diffusion processes** so that there is an exchange of information between the disseminators and potential adopters and the resulting improved cookstove design incorporates both the needs of the latter and the efficiency and/or pollution concerns of the former.

* **The designer/disseminator's frequent assumption that the potential adopter's priorities are identical to his or her own is generally unwarranted.** Most improved cookstove programs could benefit by carrying out some market research before attempting to design an improved cookstove or introducing such a stove.

* **Operator education, follow-up and extension services, and monitoring and evaluation are critical components of the dissemination program.** The dissemination effort cannot end with the installation of the improved cookstove. Operator education, follow-up and extension services, and monitoring and evaluation all have important roles to play if any permanent change is to come about.

* **Most improved cookstove programs are doing more than introducing a new stove or a piece of equipment.** They seek to change the way people cook. Food habits, like other personal habits, are deeply rooted and are not easily altered. It should not be surprising, therefore, if improved cookstove programs meet with resistance. Change comes slowly and may not occur within the project's life time.

* **Improved cookstove programs should be explicit in stating their goals and selecting their measures of success at the outset so that evaluation is facilitated.** Stoves may be designed to maximize efficiency, to minimize pollution, or to achieve some combination of the two objectives. It is imperative that the relative emphasis placed on each of these goals in the design of the improved cookstove and the dissemination program be the result of a deliberate and conscious decision; in the absence of such an explicit statement of goals, evaluation of program results becomes difficult. It would not be unusual to discover at the program's end that neither of the objectives has been met or that one has been achieved at the expense of the other.

* **The dissemination program should be structured to avoid placing undue emphasis on one portion of the program at the cost of others,** even if it is less easy to produce tangible evidence of the importance and need for some phases of the program (for example, follow-up and extension services, monitoring and evaluation).

* **Large-scale dissemination programs are hard pressed to control quality and simultaneously preserve their flexibility.** Arguments can be made in favor of large-scale or small-scale dissemination programs but, in general, it

is more difficult in large-scale programs to maintain standards and control quality and, at the same time, preserve a measure of flexibility so that the program remains responsive to the particular requirements of cultural groups and physical environments.

Many of these points can be illuminated by describing the dissemination programs under which the improved cookstoves in Garhibazidpur, Keelara, and Pallerayanahalli were built. In fact, the findings presented in Chapter 4 must be viewed in light of these differences in the dissemination programs. The programs used different approaches to reach very different goals. These differences in characteristics are discussed in the next section.

Study Area Dissemination Programs

The improved cookstove program in Garhibazidpur aimed to increase fuel efficiency as well as exposures. The improved cookstove was designed with those intentions. The second port as well as the enclosed combustion chamber and the baffle and dampers are meant to improve efficiency while the flue is supposed to vent the smoke. The improved cookstove in the southern villages was designed with the intention of maximizing efficiency, the argument being that improved efficiency implies more complete combustion and hence less pollution. Also, a fuel-efficient stove is likely to require less cooking time which would reduce the amount of time the cook has to spend near the stove and, thus, her exposure.

The improved cookstove program in Garhibazidpur, a precursor of the National Program on Improved Cookstoves, was part of the National Project on the Demonstration of Improved Cookstoves and might be considered to constitute the test phase of the National Program on Improved Cookstoves. The ASTRA ole, the improved cookstove built in Keelara and Pallerayanahalli, was developed by a research group (ASTRA -- Centre for Application of Science and Technology to Rural Areas -- which is part of the Indian Institute of Science, Bangalore) and the stoves were constructed in a pilot dissemination project by ASTRA itself. Improved cookstove dissemination programs can differ in many ways. Among the relevant distinctions are the manner in which the following components of the program are organized and managed: general structure, need assessment, choice of stove design, training of stove builders, subsidies, operator education, follow-up and extension services, and monitoring and evaluation. Both the National Project on the Demonstration of Improved Cookstoves and the Centre for Application of Science and Technology to Rural Areas' dissemination programs are discussed under each of these headings to highlight their respective goals and philosophies. Much of the following information is drawn from field notes.

General Structure: The National Program on Improved Cookstoves3 is sponsored by the Department of Non-Conventional Energy Sources of the Government of India and is implemented by various state governments and non-governmental organizations. The Department of Non-Conventional Energy Sources sets the annual target which is expressed in terms of the number of improved cookstoves to be built. The non-governmental organizations negotiate their individual goals with the Department of Non-Conventional Energy Sources. The ultimate aim of the Department of Non-Conventional Energy Sources is to have an improved cookstove in every rural household; villages are declared to be "smokeless" when all the households have improved cookstoves or biogas plants. There are 8000 smokeless villages in India today and in a further 10,000 at least 75 percent of the households have improved cookstoves (Garg, 1987). In the National Project on the Demonstration of Improved Cookstoves, the focus was on installing stoves. Very little attention was paid to post-installation services, performance, and evaluation. The importance of these aspects of the dissemination program soon became evident and the current program, the National Program on Improved Cookstoves, is more conscious of it (Upadhyaya, 1987).

The stoves at Keelara and Pallerayanahalli were built in a pilot dissemination program run by the Centre for Application of Science and Technology to Rural Areas. The group's extension center is about 5 km from Keelara and a resident staff is involved in developing and testing various energy and agriculture-related technologies applicable in rural areas. Due to the proximity of the extension center to the villages and because of the interest in performance, construction was closely supervised and follow-up services were easily available to the stove owners. In addition, owners were instructed in stove operation and maintenance. Evaluation, of course, was an important part of the dissemination program.

Need Assessment: In all the study villages the determination of need was an external decision. The selection of the individual villages where dissemination programs should be attempted was left to the implementing agencies -- non-governmental organizations in this case -- in the National Project on the Demonstration of Improved Cookstoves. The reasoning was that non-governmental organizations are more closely linked to the rural population and are in a better position to identify villages or regions where improved cookstoves may be well received. The non-governmental organizations in their turn worked with their local contacts to estimate the number of households that might be interested in new stoves and potential trainees in stove building. In the particular instance of Garhibazidpur, the non-governmental organization in question was the All-India Women's Conference and their contact was the social worker at the Kabliji Hospital and Rural Health Centre about 6 km from the village. The health center, a privately-funded establishment, was involved in various income-generating and support projects in the surrounding villages including weaving, sewing, creche and day-care programs. Garhibazidpur is Kabliji's "model" village, and the one with the best-organized group of village representatives, hence the decision to launch an improved cookstove program there. Incidentally, there had been a previous unsuccessful improved cookstove program in Garhibazidpur also conducted via Kabliji, approximately two years earlier. No visible evidence of this earlier effort remained when the new program was begun.

The ASTRA ole is currently being disseminated throughout Karnataka via a state-sponsored program but the stoves at Keelara and Pallerayanahalli were built earlier in an independent preliminary effort by the Centre for Application of Science and Technology to Rural Areas. The proximity of Keelara and Pallerayanahalli to the extension center was an important factor in the Centre for Application of Science and Technology to Rural Areas's decision to introduce the ole there. Though the shortage of cooking fuel in the Ungra area is not acute, it has increased over the last ten years or so. The extension center staff have noted, for example, growing use of dung as a cooking fuel among the lower income groups. This was almost unheard of ten years ago at the time of the first energy use survey (ASTRA, 1982).

Choice of Stove Design: The Department of Non-Conventional Energy Sources has a list of approved stove designs and implementing agencies are required to choose from this list. All the approved designs have been tested in one of four technical support units -- Indian Institute of Technology, Delhi; Punjab University, Chandigarh; Bihar College of Engineering, Patna; and Rajasthan Agricultural University, Udaipur -- and have been found to have efficiencies of at least 20 percent (for mud stoves; the minimum requirement for metal and ceramic stoves is higher). To date most dissemination programs have tried to introduce mud stoves in rural areas since these resemble more closely the traditional stove and lend themselves more readily to traditional cooking practices. The stove design used in Garhibazidpur, the Sahayog chula, was selected from the list and has been quite commonly introduced in north India. Since the stove was constructed in Garhibazidpur, the design has been adapted slightly to accommodate problems encountered in actual field use -- the dampers have been removed and the height of the combustion chamber altered.

The ASTRA ole was developed originally not as a cookstove but as a stove for making molasses in northern Karnataka where sugar production was suffering due to a shortage of fuel (Hegde, 1984). Subsequently, the designers noted the potential for adapting the design for normal cooking. This adapted design was tested in the extension center and the surrounding villages including Keelara and Pallerayanahalli. The traditional cookstove in this area has three ports as has the ASTRA ole.

Training of Stove Builders: Each of the state governments and the non-governmental organizations involved in the National Program on Improved Stoves have chula mistris (master craftsmen) who have been trained and take refresher courses at one of the four technical support units. These mistris in their turn conduct training programs where village residents are taught to build improved cookstoves. The programs run for ten days and 20 trainees build three stoves each. The trainees are usually women from the village where the stoves are to be built and they are paid Rs. 100 for their participation in the training program. The object is to establish a self-sustaining system so that once the chula mistri has left the village there will be residents capable of building stoves, training others, and answering questions regarding operation and maintenance. Once the training program is over, the trainees are paid Rs. 5 for each stove they build in the village, of which Rs. 3 is given at the time of construction and Rs. 2 two weeks later after a representative from the non-governmental organization has inspected the stove and asked the woman who cooks on it for her estimation of its performance.

In Karnataka, the extension center staff trained young men from nearby villages to build the new stoves -- many of these people were employees of the center. There was no formal training program as in the National Program on Improved Cookstoves since this was a small pilot dissemination program. One of the resident staff went along with the trainees to each of the households at the time of construction so that they received "on-the-job" training as well. The trainees were paid by the center. Now that the ole is being disseminated statewide, the training program has a structure more similar to that of the National Program on Improved Cookstoves.

Subsidies: The National Program on Improved Cookstoves provides a full subsidy for their mud improved cookstoves. The stoves are built at no cost to the householder; the householder is responsible for providing the mud necessary for the stove construction. The metal and ceramic improved cookstoves are only partially subsidized but these were not introduced in Garhibazidpur. The estimated cost of the Sahayog chula is Rs. 65.

The Centre for Application of Science and Technology to Rural Areas subsidized all the stoves built in the pilot dissemination project so the householders received the stoves free of cost. The materials for the ASTRA ole are estimated to cost Rs. 120. Currently, the state government is providing a 100 percent subsidy to low income households and a partial subsidy (65 percent) to higher income households.

Operator Education: The National Program on Improved Cookstoves has no formal system to inform householders regarding stove operation and maintenance. Trainees are told to demonstrate routine procedures to the household cook and to ask the cook to duplicate these procedures. The householders are not given any educational materials.

The Centre for Application of Science and Technology to Rural Areas had no formal system for operator education in their pilot program either and followed much the same procedure as the national program. There were ASTRA oles operating in the extension center that people could come and observe but the initiative had to be taken by the householders.

Follow-up and Extension Services: The National Program on Improved Cookstoves and Centre for Application of Science and Technology to Rural Areas' program differ most dramatically in this aspect of the dissemination program. Follow-up and extension was limited to the visit of the non-governmental organization's representative who inspected stoves in the national program and in the case of Garhibazidpur that visit did not take place. Post-introduction services were not an integral part of the national program at the time the stoves were built in Garhibazidpur. The emphasis was on meeting the target, on building a certain number of stoves within a given time period. The funding from the Department of Non-Conventional Energy Sources reflected this priority with few resources allocated for follow-up and extension services. In Garhibazidpur, the trainees proved to be inadequately prepared to provide the services on their own and there was little incentive for them to do so in any case. This probably is quite typical of the situation in other villages that were part of the early national program.

The Centre for Application of Science and Technology to Rural Areas had no formal extension program in the form of scheduled visits but since there was frequent traffic between Keelara and Pallerayanahalli and the extension center it was easy for householders to inform the center staff of their problems and obtain assistance. In addition, some of the trainees had had enough experience in stove building to solve problems as they arose in their respective villages. Householders would also stop by the extension center sometimes to ask for advice. The informal network that had developed among the householders and the extension center staff over the period of the center's existence also proved to be useful.

Monitoring and Evaluation: This was an even less significant component of the national program than were follow-up and extension services. Though there have been changes in the system since the stoves were installed in Garhibazidpur and evaluation is now a planned part of the national program, monitoring and evaluation are frequently the weakest part of dissemination programs regardless of the technology or innovation in question since their contribution is difficult to show in quantitative terms. When the program was run in Garhibazidpur there was no provision for monitoring and evaluation.

Since the programs in Keelara and Pallerayanahalli were pilot dissemination efforts, the Centre for Application of Science and Technology to Rural Areas was very concerned with performance. Once again, their ongoing monitoring and evaluation system was run not by schedule but by need. Staff who happened to be in the villages for other purposes checked the stoves and talked with the householders but this was done informally and no records were kept. They carried out an annual survey in all the villages which was more systematic. Here a sample was chosen to include households from all economic groups and castes and questions were asked regarding time savings, fuel savings, convenience, and smokiness. The information gathered was important in finalizing the design of the ASTRA ole for large-scale dissemination and for deciding the organization of the larger dissemination program as well.

In summary, then, there were basic differences in the aims of the national program and the Centre program and in the approaches they adopted in their respective dissemination programs but they also shared some similarities. At the time that the Garhibazidpur stoves were built, the national program's focus was on having a certain number of improved cookstoves installed in rural households by the end of 1984-1985. This target was used as a measure of success, installation of stoves was assumed to equal adoption; whether these stoves were functional or accepted by users tended to be overlooked and monitoring and evaluation were viewed as expensive and non-essential parts of the dissemination program (Sarin, 1986; Gusain and Khosla, 1987). The Centre for Application of Science and Technology to Rural Areas, given their interest in performance, ensured that householders knew how to use the stove, and tried to obtain feedback. The Centre benefitted from better quality control in construction as well as more effective post-installation services. Their follow-up services were informally provided but appear to have been effective. One might question how well such an approach could be replicated in a larger number of and more distant villages.

In neither case was the program instigated by village residents. The "need" was perceived by outsiders. External decisions and priorities played a major role in both programs.

Discussion

What, then, can be said about improved cookstove dissemination based on the experience in the study areas? First, the results must be viewed realistically. Surveys done in the larger national program and the Karnataka state program to disseminate the ASTRA ole show that 65 percent of the national program improved cookstoves are in regular use and that the ASTRA ole has a 20 percent rejection rate (Garg, 1987; ASTRA, 1987). Gusain and Khosla (1987) estimate the survival rate of the national program improved cookstoves to be on the order of 20-30 percent. They define "survival" as being "in working order and in use within a few months of installation." While this percentage seems extremely low, it must be remembered that the national program is trying to put a smokeless chula in every house regardless of the individual situation. It is important to consider that improved cookstoves are not introduced in a void but are displacing or replacing traditional stoves. It is unreasonable to expect an adoption rate of 100 percent. In the introduction of any innovation there will always be those whose needs are adequately met by the existing technology or situation and who are not motivated to change their behavior. The same reasoning undoubtedly applies to the adoption of improved cookstoves.

Apart from this general reluctance to disturb satisfactory or well-established routines, there may be other obstacles to adoption as well. For instance, the improved cookstove's performance would have to be consistently and significantly superior to that of the traditional stove if it is to be adopted. A traditional stove carefully tended by an experienced cook might yield efficiencies comparable to those that an inadequately-trained user might achieve on a improperly-constructed improved cookstove. Alternatively, there may be available, as in Keelara, an indigenously developed "smokeless" stove which is as or more effective in removing smoke from the kitchen. Potential adopters may not be convinced of the improved cookstove's overall desirability either if the traditional stove has multiple uses and the improved cookstove delivers better performance in one capacity at the expense of others.

Further, as noted in a review of developing country energy issues,

> the diffusion of improved solid fuel cookstoves has suffered because both solid fuel shortage and the inefficiency of traditional stoves in developing countries have been overgeneralized; the need to study the potential markets for improved cookstoves has consequently been neglected. Research is necessary to identify areas with high perceived fuel costs and the value placed by consumers on various stove improvements, including improved fuel efficiency (ERG, 1986).

This is certainly true of the study areas. Cooking fuel scarcity was not acute, and most householders gathered rather than bought fuel. Improved cookstove programs might meet with greater success if their target populations were more carefully chosen and they were implemented only in areas where people experience fuel shortages, perceive the need for fuel conservation and express a need for more efficient stoves instead of attempting a blanket coverage which inevitably produces mixed results.

Finally, reasons for non-adoption or low rates of adoption may have less to do with technical performance than with aesthetic considerations or matters of convenience which stove designers often discount or view differently. A disseminator noted, for example, that one problem with the ASTRA ole is that cooking time is too short. He said that the cook had to be far more organized, finish chopping vegetables and grinding spices before lighting the stove, because the lentils were cooked so much more quickly.

In the three villages studied, it was noticed that people tended to use the improved cookstove in precisely the same manner as they had the traditional one, that is, they did not change the rate at which they fed the fire, they did not use the dampers, and they continued to blow into the fire. This points not only to inadequate operator education in the dissemination program but also, at a broader level, to a need for the disseminators to perceive and promote the new stove as more than a piece of new equipment. As Agarwal (1986) points out, subsumed in most improved cookstove designs is a "somewhat different cooking process than that possible with open fire. To enable the user to successfully adapt the design requires familiarizing the user with the basic principles underlying the improvement." It is particularly difficult to achieve this familiarization unless there is a conscious effort to integrate the innovation and the diffusion processes (Agarwal, 1986). That such integration is possible is demonstrated by the dissemination of the Nada chula in northern India (Sarin, 1981; Sarin, 1987). When there is a two-way flow of information between the disseminators and users, the latter emerge with a sounder understanding of the technical basis for the improved cookstove design and the former are able to help develop a design that is compatible with local needs and hence more likely to be adopted. As it is the changes that the users have wrought in the Sahayog chula and the ASTRA ole have been what Agarwal (1986) would call "adaptations in use rather than ingenious improvements." She would further argue that these adaptations point to shortcomings in the original design of the stove, and that local needs were not adequately considered.

That is one way of interpreting the results. Another conclusion that can be drawn is that it is very difficult to accommodate multiple uses while maximizing efficiency and minimizing air pollution exposures. People may rely on the traditional stove for various functions but it is unreasonable to expect a manifold improvement in efficiency without streamlining the stove's functions. As Smith (1987a) has observed, this has not been the way that technologies have developed historically. High efficiency has been achieved through task specialization and the traditional cookstove in developing countries is likely to follow the same path.

Nevertheless, a chasm exists between the laboratory and the village kitchen and must be consciously bridged. Some useful lessons can be learned from the recent discussions on and experiments with social marketing techniques, especially in the field of health education (Manoff, 1985; Brieger and Ramakrishna, 1987). Much of the work done has been related to breast feeding, oral rehydration therapy, and contraceptives. Many would argue that the value of social marketing has been overstated but the relevance of its basic principles is clear. Two of its fundamental precepts seem to be that need for the product must be expressed in the intended market and market research should be used to hone product design. Disseminators must go out into the field to find out what people need -- their input is critical to the design of a successful product. This ties in with Agarwal's (1986) comment that adaptations in use are an indication that the dissemination program did not adequately assess and respond to local needs. If the product requires behavioral change rather than adoption of an artifact per se (or both) then one must go into the field to find out if the message is being heard as it was intended and whether it can be better expressed.

Where fuel is not particularly scarce, householders may be more interested in non-efficiency attributes of the improved cookstove such as smoke removal or time savings. This has been demonstrated in large-scale surveys done in the past and in the present data. Bajracharya (1983) noted in the course of his fieldwork in Nepal that improved-cookstove adopters often made their decision to keep the new stove because it removed smoke from the cooking area rather than because it improved fuel efficiency. The Centre for Application of Science and Technology to Rural Areas (1987) surveyed 2200 households across Karnataka state and found variations in fuel savings but observed that "the success of the stove in eliminating smoke is...much more satisfactory and its broad acceptance might be attributed essentially to this reason." Joseph (1987) in a survey of surveys reached much the same conclusion. In Garhibazidpur, the improved cookstove had a high attrition rate and were difficult to find toward the end of the study period. Those that survived did so in altered states, the most common modifications being the removal of the second port, the dampers and baffle so that what remained was essentially a traditional u-shaped stove with a chimney attached. The chimney was clearly the one component of the improved cookstove that users appreciated and wished to retain. Similarly, users may be seeking qualities in improved cookstoves neither foreseen nor considered critical by designers. Such gaps between the potential owners' priorities and the designers' priorities indicate a need for more field work or for market research, as the current terminology would have it.

The decision of whether the improved cookstove should be subsidized is another critical factor that affects the nature of the dissemination program. Both the improved cookstoves in the study areas were fully subsidized so as to make them available to those sections of the population that most needed them. While this is a reasonable rationale, subsidies sometimes raise other problems because people tend to view a freely-given product or service differently than they would one that they have paid for. This difference in attitude may express itself in several ways:

> Because people will not place a value on a free good...it is often difficult to persuade people to come and be trained, to spend the necessary time to build the stove and use it properly. They will need convincing that the stove really will save time in cooking or collecting wood and...people can take a lot more convincing over a free good than one which they have paid for (Stewart et al., 1987).

These are not issues peculiar to improved cookstove programs but are shared by many programs that disseminate common-good innovations.

A major problem with the dissemination program in Garhibazidpur, and possibly with the national program in general, is quality control. There were many defects in initial construction of the stoves and these compounded with inadequate operator education and follow-up services were enough to cause many to abandon the new stove rapidly. If quality control is not an inbuilt and automatic part of the program, maintaining standards and some degree of uniformity in a program of this size becomes impossible. The process may be simpler if the specifications are given in units that are easily understood and checked and the design is resilient, that is, small deviations from the prescribed measurements do not result in large reductions in efficiency or increases in exposures. Similarly, once the stove is installed and is in use, maintaining quality would be less of a concern if the stove were designed to be less sensitive to operator behavior. The traditional stove with a hood in the southern villages is an instance of such a design: when constructed well, it remains "smokeless" regardless of operator behavior. This would also lessen the need for operator education and changing cooking practices. The challenge is to develop a stove that is fuel efficient, reduces exposures, and requires no change in the user's behavior.

Conclusion

Though improved cookstove technology may be simple relative to other modern technologies, it operates in a complex cultural context. If this context is not well-understood and the improved cookstove is not designed for a particular setting, the odds against an effective dissemination program are extremely high. This is one of the major problems faced by large-scale, centralized programs. Though these may have advantages in terms of economies of scale and standardization of procedure, they lack the flexibility to respond to the special requirements of places and people. The National Program on Improved Cookstoves might achieve more if it operated in smaller geographic units where the target population is homogeneous and shares common cooking practices, dietary customs, and fuel supply. It is unrealistic to assume that such uniformity exists at the national level and yet too cumbersome to devise a system to ensure that local variations are considered.

Finally, it is disturbing that these problems are not new: rural development workers encountered similar situations when attempting to introduce a myriad other innovations, perhaps the most appropriate example being the latrine. It is unfortunate that the lessons of those early experiences have not been transferred. There is hope though in some of the smaller-scale programs which appear to be better-equipped to meet the situation specific requirements of improved cookstove dissemination.

Chapter 6

GLEANINGS: CONCLUSIONS AND IMPLICATIONS OF FINDINGS

The limitations of methodology and data analysis notwithstanding, it is clear that the spatial variations in physical and cultural characteristics affect not only the pattern of domestic air pollution but also the reception of improved cookstove programs. The extent and nature of these influences are discussed in this chapter. The general as well as the specific findings regarding air pollution studies, perception surveys, deforestation, dissemination, development, health are elaborated. Finally, the implications of these results for future research in geography are discussed, and the chapter concludes with a brief postscript on domestic air pollution and development issues.

Principal Findings

The search for patterns in domestic air pollution had some unexpected outcomes. Exposures to TSP were high in all villages, regardless of location, stove type, or kitchen arrangements. CO concentrations were relatively low and, in most cases, were below levels that arouse concern. The natural variability in the data is very high, obscuring in many cases the relationships of interest between the different variables. The effect of the cultural and environmental factors being investigated was difficult to determine. This in no way implies that these relationships do not exist or could not be detected given a different study design.

The influences of some of the factors were distinguishable. In particular, the location of the kitchen in Garhibazidpur and the roof type in the southern villages affected air pollution concentrations and exposures. Higher CO concentrations were found in indoor kitchens than in protected or outdoor kitchens. There was a statistically significant difference in CO concentrations among the rooftype categories in the southern villages. Concentrations in poorly ventilated kitchens of old, mud houses often remained in the 50-100 mg/m3 range throughout the cooking period. These houses are being replaced by better-ventilated tile and brick houses. New housing, which features in development programs in some rural areas, offers opportunities to improve indoor air quality through architectural design that provides ventilation while accommodating cultural preferences.

TSP exposures were found to be similar in households with traditional stoves and improved cookstoves; the small differences observed were not statistically significant. The addition of a hood to the traditional stove in the southern village resulted in low TSP exposures, much lower than the unmodified traditional stove ($p<0.001$). This indigenous solution to domestic air pollution appeared to be more effective than the improved cookstoves but the reduction was not statistically significant. In all cases, however, the exposures measured exceeded the established standards by an order of magnitude.

Carbon monoxide concentrations were lower in southern kitchens where the new stove was in use and the difference between these kitchens and those using traditional stoves was statistically significant. The lowest CO levels like the TSP exposures were found in kitchens that had the traditional stove under a hood. In general, CO levels were not high enough in any of the villages to cause concern. In Garhibazidpur, the CO levels were neither high nor was there a statistically significant difference between the old and new stoves.

Although there was much natural variability in the TSP and CO data, the full range is probably not represented in these data since they do not contain the higher concentrations and exposures that might be expected in the monsoon when ventilation is severely limited and fuel moisture is higher. As mentioned earlier, a measurement in "simulated" monsoon conditions in Gujarat yielded a peak concentration of 56 mg/m3 (Smith et al., 1983). Therefore, the calculated averages are probably conservative.

There was no statistically significant difference in the TSP and CO means when the data were organized by kitchen construction material, fuel type, fueling rate, ambient temperature, and relative humidity. One must reiterate though that this lack should not be taken as proof that these factors are not related to air pollution exposures and concentrations. The natural variability in the data obscures many of the interactions; increased sample size and better control may overcome this noise in the data.

Some of the findings of the survey are contradictory at the superficial level. People do perceive air pollution as a nuisance and a problem but the majority have not taken any action to remedy the situation. The exceptions are those who have installed hoods over the traditional stoves, an option not available to those who live in thatch houses. Also, though people may view domestic air pollution as a problem, that perception occurs within a wider context. More pressing considerations intervene including the difficulties of meeting basic needs. Their priorities for action are determined by this broader picture: domestic air pollution does not threaten survival in the shortterm.

People can also distinguish between cooking fuels on the basis of smokiness but make no special efforts to obtain less smoky fuels. In Garhibazidpur this may be because many people are already using keekar, the fuel identified as least smoky, which is readily available at roadsides but its thorniness makes fuel collection hazardous. Procuring a less smoky fuel in the southern villages, on the other hand, might entail some monetary expenditure since "large pieces of wood" must be bought and are not to be had gratis.

Finally, the survey asked people to evaluate the new stove. It received a positive evaluation in the southern villages while there were many complaints about the new stove in Garhibazidpur. The reaction in Garhibazidpur agrees quite well with the air pollution measurements but not so in Keelara and Pallerayanahalli. People perceived the new stove to be a great improvement over the old stove in conserving fuel, decreasing the amount of smoke in the kitchen, and the amount of time needed for cooking. The measurements reveal quite a different picture. These favorable reviews did not extend to improvement in health conditions: in both areas, a large number of people said they had observed, in general, no change in health since the introduction of the new stove. A common response in both places was that they had noticed less eye irritation since using the new stove.

What is the significance of these findings? There are implications of both a greater and lesser nature for air pollution research and perception surveys as well as insights regarding improved cookstoves, deforestation, development, and dissemination. These are discussed in the following section.

Lessons Learned: Directions for Research and Action

Improved Cookstoves: It is disquieting to note that neither of the new stoves reduce TSP exposures below established standards. Other studies have found improved cookstoves to produce a statistically significant reduction in exposures (Reid et al., 1986) but there is no unanimity in the evidence so far. To further complicate matters, Smith and Durgaprasad (1987) found measurable TSP exposures in kitchens where biogas stoves were in use. They suggest that smoke from traditional stoves in nearby kitchens raised ambient TSP levels which in turn contributed to elevated concentrations in biogas-stove kitchens. Such circumstances are common in and relevant to regions such as north India which are prone to thermal inversions in the winter that can trap pollutants a few meters from the ground. This means that regardless of the smokelessness of a given stove in a particular household, domestic air pollution may remain a problem if only a portion of the village adopts stoves that are smokeless. It would also appear that, depending on the objective of the program, improved cookstoves can be seen as intermediate solutions, at best. Eventually, attention must turn to developing, testing, and introducing cleaner-burning processed biofuels (charcoal briquets, for example) with superior energy quality.

Besides these technological considerations, any attempt to introduce change that is not sensitive to present practices and traditions is unlikely to be well received. It would be prudent to conduct a market survey in potential improved cookstove dissemination areas to ensure that there is some consonance between what the local people need and what the disseminators have in mind. In the study area, for example, the survey showed that most householders gather cooking fuel rather than buy it and that crop residues and dung account for a large proportion of the fuel that is burned. As long as this remains true, it will be difficult to initiate changes that require purchase of fuel. Also, as long as the amount of time required to gather fuel is not perceived to be prohibitive by householders, fuel conservation as an issue will not assume urgency.

Change that arises from existing conditions is more likely to be sustained. Opportunities for such change should be sought and exploited. An example is the hood over the traditional cookstove in the southern villages. The main strengths of the modified traditional stove are its simplicity and its dependability: the probability of malfunctions is relatively low. At present the hood has a limited range, due to constraints imposed by size and cost. If it were constructed of cheaper and lighter materials, it might be suitable in wider variety of situations especially when combined with an efficient portable metal stove. Such a combination would be particularly useful in urban areas or where the location of the kitchen shifts frequently. A stove-cum-hood package might find a niche in Garhibazidpur, for example, where outdoor cooking is the norm for a significant portion of the year. Some arrangement would have to be made to accommodate roti-making but the basic idea of combining a stove designed to maximize fuel efficiency with a hood with a nearly failsafe ability to remove smoke from the cooking area needs to be examined seriously.

Air Pollution Studies: This field study and the work done by Boleij et al. (1987) show an enormous variability in air pollution data. Coefficients of variation of 65-70 percent were calculated. This may be in part a function of the small sample sizes involved. With that caveat, it might be argued that the apparent variability is such that repeated measurements in the same kitchen can be treated as independent measurements. This has obvious implications for the design of future studies, namely, that they can be of shorter duration and still collect an adequate sample. Where seasonal differences (in fuel type or characteristics, kitchen location, or climate) are a significant factor, further consideration of study design will be necessary. Large sample sizes will also be required to overcome the variability in the data and to detect patterns and relationships.

Another approach to this study might be to use a case-control design where the controls are houses with traditional stoves. The houses could be matched by location of kitchen and construction material, thus eliminating some of the variability. By doing this, it might be possible to draw conclusions that have greater statistical significance. Much depends on the greatest source of variability -- if this happens to be operator behavior or some similar variable, control will be difficult.

Alternatively, an intervention study that measures air pollution exposures and health effects before and after introduction of new stoves might be in order if the aim is to evaluate the effectiveness of improved cookstove programs. Such a design would provide a control for comparing the performance of the new stoves. Ideally, the monitoring would precede introduction and be repeated a few weeks later when the cooks have become accustomed to the new stove and the stove itself has been seasoned by regular use. Once the new stove has been introduced, it is debatable whether a fair estimate of air pollution exposures from traditional stoves, even in households where traditional stoves are used exclusively, can be obtained. The cook's behavior might be affected by the concern and publicity regarding fuel efficiency and smokiness that frequently accompany improved cookstove programs.

Finally, this field study reconfirmed the need for more personal monitoring of exposures in rural areas of developing countries. Almost all previous research has involved area monitoring which, at best, gives a gross estimate of exposure. Concentrations vary so much spatially that, given the present state of technology, personal monitoring is the only means of measuring exposure with any accuracy. These variations occur not only horizontally, depending on the distance of the cook from the stove but also vertically since pollutants have a strong tendency to stratify, with concentrations increasing with height (Menon, 1988). Pollutant concentrations also vary temporally with higher levels occurring at the beginning and end of burn cycles. Hence, the movements of the cook are of prime importance in determining exposure, and personal monitors allow her to pursue her normal activities while measuring her exposure.

The primary limitations of the present study are the small number of villages (three) studied and the relatively small sample size in each village. If I were repeating the study, I might select a larger sample size and alter the study design. Based on the results of the present study I can determine the differences in means in the study areas and the coefficients of variation for the data set. With this information it is possible to calculate the minimum sample size needed in each cell (Table 36). For instance, in Garhibazidpur the difference in TSP mean exposures between the old and new stoves was only 12 percent. To prove this difference at the five percent confidence level would require a sample of 100 in each cell of the sample. In the southern villages, where there was a 48 percent difference in means between the traditional stove and the traditional stove under a hood, the minimum sample size in each cell is 11, which is manageable. One might question the usefulness of detecting and proving small differences in means; so many factors affect exposures that a ten percent difference in means is negligible. Also, given the magnitude of the exposures, a 10 percent reduction is unlikely to change health, environmental, or aesthetic impacts.

Perception Surveys: The survey was valuable mainly in providing a glimpse of a different world view, the perspective of the rural Indian woman. Recognizing the existence of a rift is only the first step in the process; as Kothari (1987) remarks:

> ...we live in a deeply divided world with increasing loss of contact and growing estrangement between people. It is an estrangement that not only promotes ignorance and loss of empathy, but, through capsuled stereotypes and in-built prejudices, creates a psychic condition of growing immunization, apathy, and amnesia (Kothari, 1987).

The fight against "immunization, apathy, and amnesia" can be arduous for the urban/rural divide is a fundamental one. Of all that separates people this one factor has caused much misunderstanding and strife. It is not an easy gap to bridge from either direction. Since development programs are heavily urban in conception and planning, there is a need for more perception studies in rural areas of developing countries in order to better understand the priorities of rural householders and their perception of their own situation and the alternatives for action. This survey made a preliminary effort to do this but more could have been done. It would have been useful to include in the questionnaire, for example, a list of rural hazards and problems including domestic air pollution and to ask householders to rank these various risks. That would have helped in interpreting the answers to the question regarding what action has been taken to ameliorate domestic air pollution.

What the survey did make abundantly clear, though, was the difficulty of collecting information on perceptions, in deciding which questions to ask and, later, in interpreting the answers. The results of the preliminary survey guided the first decision. Open-ended questions were used to encourage spontaneous

Table 36

Minimum Sample Sizes for Various Percent Differences in Means and Coefficients of Variation
(Level of significance = 5%)

PERCENT DIFFERENCE IN MEANS	COEFFICIENT OF VARIATION 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
5	23	92	208	370	578	832	1133	1480	1873	2312
10	6	23	52	92	144	208	283	370	468	578
15	3	10	23	41	64	92	126	164	208	257
20	1	6	13	23	36	52	71	92	117	144
25	1	4	8	15	23	33	45	59	75	92
50	1	1	2	4	6	8	11	15	19	23
100	1	1	1	1	1	2	3	4	5	6

Note: The sample size refers to the number of data points needed in each sample.

responses. While this end was achieved, new problems of interpretation were created.

The survey was conducted toward the end of the study period so that maximum time was available to develop a rapport with the people in the villages, and to become familiar with their view of the world. This is a two-way process, however, and the householders had an equal opportunity to learn my perspective. How did this affect their responses? Agarwal (1986) quotes Mamdani who records an interviewee in a Punjabi village explaining, "Babuji, someday you'll understand. It is sometimes better to lie. It stops you from hurting people, does you no harm, and might even help them." Such reasoning often influences the responses elicited; to expect otherwise would be unrealistic.

The open-ended questions and informal conversations did, however, convey a sense of the differences in priorities between the rural poor, the urban middleclass and the academic bourgeoisie. Redclift (1987), in his discussion of ecodevelopment and sustainable development, addresses some of these issues. He cites Chambers to support his contention that it is the "enlightened rich" who are concerned with sustainability and productivity while the poor are preoccupied mainly with their immediate livelihood. He argues:

> The perspective of the poor is at variance with that of most economists and biologists, placing the immediate satisfaction of needs and the avoidance of risk before sustainability or higher productivity. Similarly the time horizon of the poor is shorter, the future valued much less than the present.... What poor people pursue through the development process and their use of the environment, is simply a better livelihood (Redclift, 1987).

This is the background against which improved cookstoves are being introduced. The priority is survival and risk avoidance is an important part of the survival strategy.

Another part of the background that has been widely misrepresented and which has to do partly with perceptions is deforestation. Improved cookstoves are promoted the world over for their increased fuel efficiency and statements of purpose often estimate the hectares of forest or the cubic meters of wood being saved as the result of dissemination programs. A closer look in the study areas showed that the relationship between cooking fuel use and deforestation is not as straightforward as it is made out to be.

<u>Deforestation:</u>

> The logical chain between firewood consumption, deforestation, and desertification is weak and partly misconceived. The use of firewood does not necessarily or frequently lead to deforestation.
>
> Deforestation is a strictly regional problem, and is to be encountered in two types of situations: where land is being cleared for agriculture, as in Brazil and Indonesia (both of which are exporting wood to industrial countries); and where strong demand in nearby urban centres uses up wood for two main purposes (i.e., construction and

combustion), for instance, in Nepal, parts of China, and parts of Africa.... It is important to discuss deforestation in a regional context, however, because the reasons for deforestation, the reasons for concern, and the remedies will be different in each region (ERG, 1986).

Decreasing fuel consumption and consequently reducing the rate of deforestation has long been used as a justification of improved cookstove programs in India. As noted earlier, crop residues and dung are common cooking fuels, more ubiquitous in some places than fuelwood. By decreasing fuel consumption, crop residues and dung are being saved, not fuelwood. Achieving this saving can be a useful objective in itself as there are often alternative uses for dung and crop residues. It is necessary, however, to recognize explicitly what goal is being met and to be clear about the significance of that goal. It is primarily urban demand for fuelwood and timber rather than rural use in cookstoves that contributes to deforestation. This is not to deny that deforestation is a serious problem in some parts of India and the world or that ameliorative action is needed in these areas. The situation will not be helped, though, by improved cookstove programs in most places, granting that programs in urban areas might have an impact. Regardless, it is not necessary to use deforestation as a justification: many other legitimate reasons to develop and promote improved cookstove programs exist.

Development:

> Unlike the developed countries where the energy crisis occurs in association with qualitative changes in tastes and preferences, and vertical shifts in economic conditions, in low-income countries such as India the energy crisis occurs as a spatial symptom of underdevelopment and spatial disorganization of economy and ecology (Dasgupta and Maiti, 1986).

> ...in less developed countries rural areas are dedicated to agricultural production rather than consumption by urban groups. Multiple land use is rare. In such areas environmental problems are development problems. The conditions under which environmentalism became established in North America and Europe do not exist (Redclift, 1984).

Environmental quality cannot be separated from development not because the price of the latter is an inevitable deterioration in the former but because most environmental problems in developing countries are, as Redclift argues, at their root problems of development. That is certainly the case with domestic air pollution.

Besides the obvious link with environmental quality, the domestic air pollution issue has implications for future rural energy options. As wood becomes increasingly scarce, people shift to other "free" fuels, that is, to crop residues and dung; this process is observable in the southern villages. There are, however, alternative uses for these resources, especially dung which is normally applied to the fields and is important in maintaining soil quality. Though rural electrification proceeds apace, the first priority is lighting rather than cooking. It is improbable that the emphasis will change, given the expensiveness of electricity and the temporally uneven demand that its use for cooking would produce. In addition, the initial investment necessary to pay for electric stoves and house connections exceeds the resources of the majority of the rural population. The need to develop alternative cooking fuels, whether they be upgraded processed biofuels or some new fuel, and make them accessible to the rural population is clear.

At a more basic level still, it has been contended that a "clean kitchen" and an "efficient kitchen" should be basic needs as are adequate food, water, shelter, and health care (FWD, 1987). This makes sense from a practical, as well as philosophical, point of view. Rural cooks spend a significant portion of their lives in these environments and with them often are infants and children. For the cooks, at least, it is an occupational hazard and should be treated as such. Reducing domestic air pollution is not simply a matter of introducing an improved cookstove but also of altering ventilation and changing the kitchen environment, in general. The stove-fuel-kitchen complex is what needs to be changed, not the stove alone.

That there is more to development than meeting basic needs has been stated repeatedly in the ongoing debate on what "development" means or should mean. Development is also "empowerment", providing people with opportunities to realize their potential for improving their own lives, to organize themselves and act cooperatively to further common interests. Besides the direct benefits of improved cookstoves, dissemination programs could also help rural women become involved in development activities and encourage the growth of their organizational skills. That such mobilization is possible is shown by the experiences of Madhu Sarin in Nada village (Sarin, 1986). The importance of improved cookstoves should be kept in perspective though: they are not the panacea for all rural ills.

<u>Dissemination:</u>

> Tall claims by technical institutes notwithstanding, no breakthrough has been made in the basic technology for over 40 years. Technically, the Magan Chulha of the late 1940s was as advanced as all the models of today. My fear is that even after 40 years of experience, we are making the same mistakes as were made by the Gandhian promoters of the Magan Chulha then -- i.e., not giving due attention to the finer details at the household level which make the chulha take root there or not (Sarin, 1987a).

Perhaps there have been a few technical advances since the Magan chula but Sarin's point is well taken: it is not sufficient to have a rigorously tested improved cookstove that performs well in the laboratory. Without an equally well-implemented dissemination program, the stove is unlikely to be adopted. And as has been noted, for the best results, innovation and diffusion should not be separate processes. Innovation should be based on field research that shows what the potential users need rather than on what urban technicians think they should have. The integration of these two processes is neither simple nor could a standard procedure be recommended. The guiding principles should be the provision of opportunities for feedback from the field and allowance of sufficient time in the project schedule for interaction between designers and users. The practical implications are daunting for the necessary investment of time and resources in the early phases of the program will be formidable. Before judging the proposal hastily as unfeasible, integration of innovation and diffusion should at least be experimented with as an ideal objective.

While debate continues about the value and applicability of social marketing in arenas ranging from public health to rural development, some of its basic concepts might be useful in improved cookstove dissemination. Specifically, the idea of working from end user to product rather than vice versa is perhaps most relevant and important. This, like the integration of innovation and diffusion, is time and resource consuming, more so possibly than most dissemination programs are able to expend, given the structure of funding. As in the previous case, though, it is a worthwhile goal to strive toward.

Besides the varying concerns of the dissemination programs and potential adopters, the conflicting time perspective of the two can also create problems. It is a curious mixture of shortterm and longterm views and, unfortunately, the perspectives do not coincide. On the one hand, the timeframe of the disseminators is short, they must move on to the next village. On the other hand, change in the village, particularly in cooking practices, comes slowly, and often cannot be persuaded to occur within the life of the project. The stove, however, is often promoted on the basis of its indirect future benefits. The householders' weighing of costs and benefits is strongly influenced by present considerations.

There are many ways, then, in which a dissemination program can be derailed. Oversights, miscalculations, and hidden agendas make the path hazardous. Certain policy decisions could increase the chances of success. Most dissemination programs could be strengthened, for example, by a greater stress on education. As Sarin (1987a) emphasizes, both the stove builder and the stove user must understand the principles on which the improved cookstove design is founded. These are sufficiently alien relative to traditional stoves to require considerable education and training. Unfortunately, neither education nor training is easily accomplished, both requiring substantial inputs of time and effort. Unless they are formal components of the dissemination program that are monitored and evaluated, there is no incentive for chula builders or supervisors to spend much time teaching users how to operate the improved cookstove, how to maintain it, how its components relate to each other, or how modifications will affect fuel efficiency and smokiness. The measure of the dissemination program's performance must be something broader than the number of stoves installed: that information in itself conveys nothing.

Another critical part of dissemination that is underemphasized is monitoring and evaluation. Feedback based on previously determined measures of performance is necessary for quality control and program improvement. This is the downfall of most development programs because usually neither funds nor personnel are specifically designated to cover these components and evaluation is often an afterthought that is not discussed adequately in the planning phase.

Although expressed variously, these comments have a common message: there is a need to realize that improved cookstove programs do not seek merely to disseminate a new technology. They seek to alter deeply embedded behaviors and practices related to cooking. These changes will not come easily or quickly, and certainly not if the objective of the dissemination program is viewed narrowly to be simply the installation of improved cookstoves.

In addition, like the extent of deforestation, the demand for improved cookstoves has been overgeneralized. This explains partially the apparently poor results of many dissemination programs. Where fuel scarcity is not acute, fuel conservation not a primary concern, and domestic air pollution not significant, the need to introduce improved cookstoves is questionable. The "market" for improved cookstove programs needs to be selected more carefully; smaller geographic units that are homogeneous in cooking practices and fuel base are probably more appropriate than political or administrative units.

Many different dissemination strategies are required then because of the great spatial variations in culture and resource base. The answer to the basic question, "Which stove for what purpose where?", varies tremendously even over short distances. At a still more micro level, there are inequalities within individual villages that must be taken into account in choosing a dissemination strategy. These arise as a result of variations in the availability of and access to fuel, family labor supply, intercaste variations in diet and cooking habits, and so on. In short, there is no universal dissemination strategy guaranteed to work in all situations just as there is no universally acceptable cookstove design. In both cases, spatial variations in cultural and physical factors must guide the choice of appropriate strategies.

<u>Health:</u> In part because of the difficulty of measurement, the health impacts of exposure to domestic air pollution were not investigated in the course of this study. The few questions regarding the perception of health effects were the extent of data collected on the topic. This is, however, clearly a public health problem deserving attention and an area for further research. As mentioned earlier, longitudinal or prospective epidemiological studies which combine health status information with air pollution exposure data obtained by using personal monitors would be useful. So far no definitive conclusions have been derived from general population samples using ambient air quality data for chronic exposures. Acute exposures that occur during air pollution episodes, for example, have been linked to excess morbidity and mortality. The methodology used in this study could be adapted for research on the health effects of domestic air pollution. Though this is not a study in medical geography, the exposure data collected in its course could be of use in designing such a study, as they give an indication of the magnitude and pattern of the exposures.

One might ask whether there is need for such work or for detailed epidemiological research. It is necessary to view domestic air pollution in the context of prevailing conditions in rural India. It is more than a nuisance but it is not the most pressing problem. It contributes to poor environmental quality, exacerbates many chronic respiratory diseases and may, in the long term, lead to conditions such as cor pulmonale. The aetiology of chronic respiratory diseases is difficult to pin down; much might be invested conducting such research with few definite conclusions. Perhaps for policy purposes one should conclude on the basis of available information that these levels of air pollution are undesirable and should be reduced regardless of proof on specific health effects.

Implications for Research in Geography

One of the key conclusions of this study relates to the spatial variation in physical and cultural characteristics which influence domestic air pollution and determine the effectiveness of improved cookstove programs. These variations are not random; distinct regions based on fuel and diet can be distinguished in the state of Karnataka, for instance (Ranganathan and Subba Rao, 1987; Ravindranath et al., 1987). The importance of acknowledging these variations and tailoring dissemination programs to them cannot be overemphasized. The effectiveness of dissemination strategies employed by the various improved cookstove programs, and by development programs in general, is determined largely by their cultural and economic context. The reawakening regional approach in geography could be ideally employed in defining these variations. The real data about the particulars of rural life come from micro level studies, similar to this one, which are a necessary stage in the process of understanding. For the purposes of policy-making and planning, however, a broader view is essential, and this is where the integration and perspective that geographers can provide comes into play.

More specifically, while the present study may have raised more questions than it answered, it has shown several opportunities for research by geographers. There are many facets of domestic air pollution itself to which geographers might find it rewarding to apply their skill. Smith and Durgaprasad (1987) refer to some of these:

> The failure of some flued stoves to remove smoke from the indoor environment is due partly to problems of design, construction, and training that are sometimes observed in these programs. In addition, however, there are some important geographical factors. The relative success of improved stoves in Nepal and southern India, for example, is probably partly due to the lower housing density and ground-level temperature inversions in these areas compared to north and west India. In the latter areas, conditions are often such that a significant portion of the smoke escaping from the flues may find its way back indoors.

The present study had limited success in relating domestic air pollution to geographic factors but that does not mean that the relationships do not exist or should not be investigated. Future studies should be structured to account for the large number of factors involved, and for the natural variability in the data, both of which make for complex relationships rather than simple linear associations that are easily detected and predicted.

A possible way of doing this is to adopt an approach that moves from a regional survey of factors that affect domestic air pollution to a micro-level study of exposures, eliminating some of the sources of variability en route. This survey would aid in identifying specific regions that are particularly susceptible to domestic air pollution either due to physical or cultural factors or some combination of the two. The findings of the survey could be used to choose villages for the monitoring of air pollution exposures. The individual villages selected subsequently would clearly be representative of these regions and the conclusions of the study could be extrapolated to a wider geographic area.

Perhaps several villages from each region of India could be selected. In the present study, the villages were in places with the most obvious cultural contrast -- north and south India -- and with different fuel resource bases and climatic conditions. The number of villages had to be limited to three because of financial and time constraints. If more villages had been included, the sample size in each village would have been even smaller and it would probably have been impossible to conclude anything. Within each village, a preliminary survey was done to determine the variations in the factors that were thought to affect domestic air pollution exposures (kitchen location, construction material, stove type, fuel use patterns, and cooking habits, for example). Based on the findings, a stratified sample was selected for the monitoring of air pollution exposures. I would retain this strategy if I were repeating the study.

Issues of energy and environment in the rural areas of developing countries have not received much attention from geographers so far. Rural energy studies in developing countries, in particular, have not abounded in geography and here lie many opportunities for future work. While one may argue whether energy is the "ultimate resource" or not, it is one that is necessary for economic development and improved environmental quality. It also provides a useful point of access for the study of human-environment relationships.

Babiker's (1983) study of rural household energy use in the Sudan gives an indication of the possibilities. He divides the Nuba Mountains, his study area, into three regions and describes the differences in fuelwood supply and use in those regions. His sketch of the environmental and cultural setting provides the context for this discussion and forms the basis for deriving tentative relationships between the different variables.

The alternative approach suggested above for this study if it were to be repeated is similar to the one Babiker took. As a first step in his study he compared the spatial distribution of population and fuelwood resources in the Nuba Mountains, taking into account the rate of urbanization in the area. A parallel step in reexamining domestic air pollution would be to describe the spatial distribution of the various factors that affect exposures including the settlement pattern, that is, the horizontal and vertical distance between houses.

Returning to the methodology employed in the Sudan, Babiker used survey questionnaires, direct interviews, and participant observation to gather data. His data would probably have been more accurate had he undertaken direct physical measurement of fuel use. Such criticism notwithstanding, his study is a significant contribution for it indicates areas in geography where research is both challenging and necessary.

Another reason to appreciate Babiker's work is the overall paucity of work done to date on the geography of energy in developing countries. For instance, developing country concerns in a recent volume on energy geography (Calzonetti and Solomon, 1985) were represented by a single paper on the impact of hydroelectricity development in Amazonian Brazil. The majority of the other papers dealt with conventional fuel use in more developed countries. Further, relatively few energy geographers have dealt with renewable energy; accordingly, the book contained a total of three papers on renewable energy sources. Considering that a transition from fossil fuels appears inevitable if not imminent, this apathy is inexplicable.

There are other reasons to bemoan this lack. As Hoare (1979) has suggested, alternative energy studies may be a means by which the integration of human and physical geography could be achieved. He noted that the nature of alternative energy production and distribution is such that it lends itself well to geographical analysis. By "alternative" energy, Hoare means non-fossil fuel energy sources which tend to be decentralized in organization and administration. He contrasts this with fossil fuel energy, which

> is developed and allocated in such a way as to limit its immediate appeal to geographers. It is centrally administered by nationalized bodies or huge multinational corporations. Substantial economies of scale are involved with the capitalization of energy, which results in few "energy locations" on the ground, given the monies committed and output generated. Capital investments in the energy sector are designed for a relatively long life -- 30 to 40 years -- for conventional power stations. Finally, the local/regional impact attributable to energy developments is often very small. Some energy installations, especially nuclear ones, deliberately shun populated areas. Many use non-local labour and material inputs in construction and most generate a highly mobile set of products...which plug readily into existing distribution systems, rather than generating substantial local spin-offs.

With alternative energy sources, however, the locations of energy production and consumption, and of the producer and the consumer are usually closely associated. While one may take issue with some of Hoare's assertions, one cannot argue with his observations about the gross differences in the production and use characteristics of conventional and alternative energies and their suitability for geographical analysis. His observations can be extended to rural energy use in developing countries which is mainly non-fossil fuel and thus shares the characteristics of what Hoare calls "alternative energy."

Wilbanks (1985) further contends that "mission-oriented" basic research in energy geography that focuses on "issues rather than on defining boundaries (offers) chances to get close to the essence of how human systems work." He suggests that research "arising from questions about society rather than questions about geography itself" might revitalize the field and emphasizes that being relevant need not engender the loss of professional standards or the development of theory and methodology.

Support for that contention comes from one aspect of energy geography that has been studied, that is, the behavioral variables in energy consumption. Once again, however, the emphasis has been on conventional energy use in more developed countries (see, for example, Jackson, 1988). Research has also been undertaken on the perception of pollution in the industrial centers of countries such as India (Bladen and Karan, 1976; Karan, 1980; Karan et al., 1986). Similar behavioral energy research and perception research in rural areas of developing countries is needed.

At a broader level still, the relationship between development and environment is one that geographers need to examine more closely. It is a topic that receives much rhetoric from geographers and non-geographers alike but benefits from few concrete research results. It is an issue fundamental to developing countries but remains at the center of unresolved controversy. From a practical point of view, this is unfortunate. There is no basic dichotomy between environment and development though they are often treated as if there were. Environmental quality, development, and rural energy issues cannot be addressed separately in developing countries. Some of the links are obvious but the interconnections are inadequately defined and understood. A clearer comprehension of the dynamics would be useful not only for practical reasons but also as a means of achieving the long-sought integration of human and physical geography (O'Riordan, 1971; Mabogunje, 1984).

Such are the repercussions of human resource use and the ensuing problems of environmental quality that they require an approach that combines the traditional perspectives of human and physical geography. It is unfortunate that the reaction to the environmental determinism of the turn of the century was an almost complete separation of human and physical geography, especially in the United States. The reason for the tardiness of the discipline's response to the environmental movement of the 1960s and 1970s lies partially in this split. Geography has also tended to trail the other social sciences in the development debate, echoing rather than leading the evolving polemic. One is inclined once again to attribute this reticence to the divide in geography which hinders an integrated approach to the issue. This is probably where its contribution would lie, in showing that in any given region a combination of factors produce patterns of development and underdevelopment, rather than any single factor. As Redclift (1984) elaborates:

> Poverty is everywhere the outcome of specific relations between the natural environment and socioeconomic structures. To ignore the specificity of these relations, to equate poverty in the Sahel with poverty in the Andes, or Bangladesh, is to reason from outcome to causes, a posteriori. Human poverty makes physical environments poorer, just as poor physical environments make for greater human poverty. What needs to be recognized is the specificity of the relationship between structural factors and those of the natural environment.

The specificity of such relationships provides geographers with a focus of study that might prove fruitful, both in developing theory and in producing practical results. In a similar vein, Brookfield (1983) called for geographers to "return to their roots", to strengthen regional studies once again, and thus provide a context for theoretical contributions in the study of development.

To make the most of these opportunities what is needed, perhaps, along with the often repeated geographer's claim to synthesis is a broader view which is cognizant of the problems of society as well as of problems in geography, as Kates (1987) urges in the following passage:

> Things are falling apart; the disciplinary centers are not holding, not only in geography but everywhere in science and art.... The formally entrenched disciplines do not map well against the great questions of both scholarship and society. Inevitably, the frontiers of knowledge are on the peripheries of disciplines; the causes of the major problems of society are multiple; the meanings of the great works are many (Kates, 1987).

Domestic air pollution may not be one of the "major problems of society" but it is symptomatic of greater underlying ills. It is essentially a problem of development and one that may cease to exist as living conditions improve. That is not to say that domestic air pollution is not a problem in more developed countries. The reverse, in fact, is true but the nature and magnitude of the problem there are different.

This dissertation has focused on the immediate causes of domestic air pollution such as type of stove and fuel. Other factors less easily quantified but which are components, nonetheless, of development broadly defined, are the root causes. These include the position of women, access to upgraded fuels, and the availability of options, all conditions that are not only difficult to change but also vary from place to place. There are, then, no easy solutions just as the causes are many and complex.

APPENDIX A

SURVEY QUESTIONNAIRES

I. Questionnaire used in Garhibazidpur

1. Name of householder   Caste

2. Occupation

   Farmer___ Shopkeeper ___ Teacher ___ Army/BSF ___ Ag. Lab. ___
   Craftsman (specify) __________ City job (specify) __________
   Other (specify) _________

3. Landholding

   Leased ___
   Owned ____

4. Livestock (include cows, buffaloes, calves, oxen)

   Total ___

5. Crops grown   Area under cultivation (acres)

   Wheat
   Sarson
   Til
   Bajra
   Grams
   Other (specify)

6. Household members

Name	Age	Sex	Relship. to head of hhld.	Education	Occupation

7. Details of house

a) Own ___ Rent ___
b) Roof type: Kucha ___ Pucca ___
c) Walls: Kucha ___ Pucca ___
d) No. of rooms: 1 ___ 2 ___ 3 ___ 4 ___ 5 ___ 6 or more ___
e) Kitchen type:
   ____ separate kitchen
   ____ kitchen cum living area
   ____ partly protected kitchen
   ____ outdoor kitchen
f) Electricity: Yes/No

8. Name of cook:

9. At what age did you begin cooking? ______ years

10. Do you do any wage labour or piece work? Yes/No
If yes, specify:

11. How many times a day do you cook?

	Morning	Noon	Evening
Winter			
Summer			
Monsoon			
Planting			
Harvest			

12. How many hours a day do you spend cooking?

	1	2	3	4	5	6	7+
Winter							
Summer							
Monsoon							
Planting							
Harvest							

13. What have you cooked or will you cook today?

Morning: Roti/Subzi/Dallia/Kheer/Other (specify)
Noon : Roti/Subzi
Evening: Roti/Subzi/Dallia/Kheer/Other (specify)

14. Do you prepare certain dishes more frequently during certain seasons or times of year? Specify.

Winter:
Summer:
Monsoon:
Planting:
Harvest:

15. (a) How many people are you cooking for today? ___________
(b) Is this the usual number? Yes/No. Usual number ______

16. How many people do you cook for during planting and harvest?
5-10 ___ 11-15 ___ 16-20 ___ 21-25 ___ 25+ ___

17. What type of fuel are you using today?

18. What type of fuel do you most commonly use in the

Winter ________________
Summer ________________
Monsoon _______________

19. Do you use relatively more cooking fuel in the

Winter ________________
Summer ________________
Monsoon _______________

20. In your opinion, what is the smokiest cooking fuel?

____

21. In your opinion, what is the least smokey cooking fuel?

____

22. In your opinion, cooking is most rapidly completed with which fuel?

____

23. In your opinion, cooking takes longest with which fuel?

____

24. What crop and plant wastes do you use in the chula?

Sarson ___ Til ___ Grams ___ Aakhada ___ Other (specify) _____

25. Is this use seasonal?

Winter:
Summer:
Monsoon:

26. What is your source of crop wastes?

Own ___
Buy ___
Given (terms) ___

27. What is your source of fuelwood?

Own ___
Buy ___
Gather ___
Given (terms) ___

28. If fuelwood is gathered:

a) How far do you go to obtain it? ______
b) How often do you go?
Every day in the winter ___
Every day ___
Every other day ___
Twice a week ___
Once a week ___
Other (specify) ___
c) Do you gather it yourself or does some other family member do it?
Self ___ Husband ___ Daughter ___ Son ___ Daughter-in-law ___
Mother-in-law ___ Sister-in-law ___ Other (specify) __________

29. If fuelwood is bought, do you buy

An entire tree _______ (price, approx.)
A cartload _______
A headload _______

30. Do you burn cow dung in the chula?

Always ___
Frequently ___
Sometimes ___
Never ___
Mixed w/other fuels ___

31. Source of cowdung:

From own animals ___
Collected ___
Given (terms?) ___
Bought (price?) ___

32. If cow dung is collected:

a) How often is it collected? ________
b) Who collects it? ____________

33. Do you use kerosene for cooking ___ for lighting ___ ?

34. Do you always use certain fuels to prepare certain foods?

Food	Fuel

35. How many cooking stoves do you have?

1) U-shaped (fixed) ________
2) U-shaped (portable) _____
3) One port w/flue ________
4) Two port _______________
5) Two port w/flue ________ (Sahayog)
6) Three port ___________
7) Three port w/flue _____
8) Kerosene _____________
9) Electric _____________
10) Other (specify) ______

36. Which stove is used for what purpose?

Stove	Purpose	Location(s)
	All purpose	
	Roti making	
	Coffee/tea making	
	Cooking for many	
	Cooking for few	
	_______________	
	_______________	

37. Does the type of stove you use change with season/time of year?

Winter ________________________________
Summer ________________________________
Monsoon _______________________________
Planting ______________________________
Harvest _______________________________

38. Does your kitchen/cooking area shift with season? Yes/No
with time of day? Yes/No

		Indoor	Location Protected	Outdoor
Winter	Morning			
	Noon			
	Evening			
Summer	Morning			
	Noon			
	Evening			
Monsoon	Morning			
	Noon			
	Evening			

39. Who built the traditional/old fixed stove?

Self ___ Family member (specify) __________ Potter ___
Other (specify) __________________

40. How old is the stove?

41. Do you have a

fixed hara? ____
portable hara? ____

42. Does anyone help you with the cooking?

Daughter ___ Daughter-in-law ___ Mother-in-law ___ Mother ___
Sister ___ Sister-in-law ___

43. Does anyone else generally sit by the stove?

Child ___ Grandmother ___ Other (specify) ___

44. Is the chula used for purposes other than the daily cooking tasks?

Cooking animal fodder ____
Heating bath water ______
Other (specify) _________

45. Does/did smoke from the stove bother you?

No ____________________
Blackens pots ___________
Blackens walls __________
Irritates eyes __________
Makes nose run __________
Causes coughing _________
Other (specify) _________

46. Have you taken any measures to reduce the smoke?

No ______________________________
Have new smokeless stove ______
Use less smokey fuels _________
Have increased ventilation ___
Other (specify) _______________

47. Do/did you find the smoke helpful in some ways?

No ____
Preserves thatch ______________________________
Keeps away mosquitoes (repellent) ___________
Preserves food ________________________________
Dries fuel ____________________________________
Other (specify) _______________________________

48. If you have a new smokeless stove in the house:

Do you use it regularly? Yes/No

If yes:

Have you noticed any changes in

a) the amount of cooking fuel consumed: Same Less More
b) the amount of smoke : Same Less More
c) time taken in cooking : Same Less More
d) your health:
    - none ______________________________
    - fewer colds ________________________
    - fewer eye problems _________________
    - less coughing ______________________
    - fewer headaches ____________________
    - other (specify) ____________________

If no:

for what reason(s)?
New stove consumes too much fuel ___________________
Takes too much time _______________________________
Difficult to get fire started ______________________
Too smokey ____
Cannot make rotis in it ___________________________
Was incorrectly constructed (explain) _____________
Location inconvenient _____________________________
Disintegrated in the rains ________________________
Other (specify) ___________________________________

49. If you have a new stove and are using it regularly and it is smokeless:

a) Do you find more mosquitoes in the house now? Yes/No
b) How do you
 - keep mosquitoes away now?
 - preserve the thatch?
 - preserve food?
 - dry fuel?

50. If you had had to pay for the new smokeless chula, how much would you have been willing to pay? ______________

51. Do any of your family smoke?

Family member # smoked/day

Questions for oldest woman in the household

52. What kind of stove did you use when you were newly married? Was it of the same type as is seen in your kitchen today?

53. What kind of cooking fuel did you use in the past? Did you use more

Twigs ______________
Logs/branches ________
Crop residues ________
Other (specify) ______
No change ___________

54. a) Was fuel more easily available then? Yes/No
b) Was it

gathered ________
bought __________
from own sources _______

55. a) Has people's diet changed in any way? If yes, explain.

b) Has the method of cooking changed in any way. If yes, explain.

II. Questionnaire used in Keelara and Pallerayanahalli

1. Name of householder   Caste

2. Occupation

   Farmer___ Shopkeeper ___ Teacher ___ Craftsman (specify) _______
   Agricultural laborer ___ Other (specify) __________

3. Landholding

   Leased/Own
   Wet land _____ acres   Dry land _____ acres

4. Livestock (include cows, buffaloes, calves, oxen)

   Total ___

5. Crops grown   Area under cultivation (acres)

   Paddy
   Ragi
   Sugarcane
   Togari
   Other (specify)

6. Household members

Name	Age	Sex	Relship. to head of hhld.	Education	Occupation

7. Details of house

   a) Own ___ Rent ___
   b) Roof type: Tiles ___ Thatch ___ Mud ___ Other (specify) _____
   c) Walls: Mud ___ Cement ___ Thatch ___ Stone ___
      Other (specify) _________
   d) No. of rooms: 1 ___ 2 ___ 3 ___ 4 ___ 5 ___ 6 or more ___
   e) Kitchen type:
      ____ separate kitchen
      ____ kitchen cum storage area
      ____ kitchen cum bath
      ____ kitchen cum living area
   f) Electricity: Yes/No

8. Name of cook:

9. At what age did you begin cooking? ______ years

10. Do you do any wage labour or piece work? Yes/No
If yes, specify:

11. Generally, how many times a day do you cook?
Morning ___ Noon ___ Evening ___

12. Do you make breakfast

_____ every morning
_____ a few times a week
_____ only during transplanting and harvest
_____ never

13. How many hours a day do you spend cooking?

1 ___ 2 ___ 3 ___ 4 ___ 5 ___ More ___

14. What have you cooked or will you cook today?

Morning: Rice/Ragi/Sambar/Idli/Dosa/Roti/Other (specify)
Noon : Rice/Ragi/Sambar
Evening: Rice/Ragi/Sambar

15. What do you cook during harvest and transplanting?

Morning:
Noon:
Evening:

16. (a) How many people are you cooking for today? ____________
(b) Is this the usual number? Yes/No. Usual number _______

17. How many people do you cook for during transplanting and harvest?
5-10 ___ 11-15 ___ 16-20 ___ 21-25 ___ 25+ ___

18. What type of fuel are you using today?

19. What type of fuel do you most commonly use in the

Summer _________________
Monsoon ________________
Winter _________________

20. Do you use relatively more cooking fuel in the

Summer _________________
Monsoon ________________
Winter _________________

21. In your opinion, what is the smokiest cooking fuel?

____

22. In your opinion, what is the least smokey cooking fuel?

____

23. In your opinion, cooking is most rapidly completed with which fuel?

____

24. In your opinion, cooking takes longest with which fuel?

____

25. What crop and plant wastes do you use in the chula?

Coconut ___ Togari ___ Pepper plant ___ Other (specify) _____

26. Is this use seasonal?

Summer:
Monsoon:
Winter:

27. What is your source of crop wastes?

Own ___ Buy ___ Given (terms) ___

28. What is your source of fuelwood?

Own ___
Gather ___
Buy ___
Other (specify) ___

29. If fuelwood is gathered:

a) How far do you go to obtain it? ______

b) How often do you go?
Every day ___
Every other day ___
Twice a week ___
Once a week ___
Other (specify) ___

c) Do you gather it yourself or does some other family member do it?
Self ___ Husband ___ Daughter ___ Son ___ Daughter-in-law ___
Other (specify) __________

30. If fuelwood is bought, do you buy

An entire tree _______ (price, approx.)
A cartload _______
A headload _______

31. Do you use cow dung as a cooking fuel? Yes/No

32. Do you use kerosene for cooking ___ for lighting ___ ?

33. How many cooking stoves do you have?

1) Trad'l one port __________
2) Trad'l two port ____________
3) Trad'l three port ________
4) ASTRA __________________
5) Electric ________
6) One port w/hood ___________
7) Two port w/hood ___________
8) Three port w/hood _________
9) Kerosene ____________
10) Other (specify) _______

34. Which stove is used for what purpose?

Stove	Purpose	Location(s)
	All purpose	
	Roti making	
	Coffee/tea making	
	Cooking for many	
	Cooking for few	
	Cooking meat	
	_______________	
	_______________	

35. If there is a traditional stove, who built it?

Self ___ Other family member ___ Potter ___ Other (specify) ___

36. How often does the stove need to be replaced?

Once a year ___ Once in two years ___ Every three ___
Every four ___ More ___

37. Does anyone help you with the cooking?

Daughter ___ Daughter-in-law ___ Mother-in-law ___ Mother ___
Sister ___ Sister-in-law ___

38. Do you generally

a) sit by the stove for the duration of the cooking period?
b) move about the house attending to other tasks while the pot is on the stove?

39. Does anyone else generally sit by the stove?

Child ___ Grandmother ___ Other (specify) ___

40. Is the chula used for purposes other than the daily cooking tasks?

Parboiling rice ____
Heating bath water ______
Other (specify) _________

41. Does/did smoke from the stove bother you?

No ____________________
Blackens pots __________
Blackens walls __________
Irritates eyes __________
Makes nose run __________
Causes coughing _________
Causes headaches ________
Other (specify) _________

42. Have you taken any measures to reduce the smoke?

No ___________________________
Have new smokeless stove ______
Use less smokey fuels _________
Have increased ventilation ___
Other (specify) ______________

43. Do/did you find the smoke helpful in some ways?

No _______________________________________
Preserves thatch __________________________
Keeps away mosquitoes (repellent) ___________
Preserves food ____________________________
Dries fuel ________________________________
Other (specify) ___________________________

44. If you have a new stove and are using it regularly and it is smokeless:

a) Do you find more mosquitoes in the house now? Yes/No

b) How do you keep mosquitoes away now?

____

c) How do you preserve the thatch of your house?

____

45. Since getting the new smokeless stove have you noticed any changes in:

a) the amount of cooking fuel consumed: Same Less More
b) the amount of smoke : Same Less More
c) time taken in cooking : Same Less More
d) your health:
none ______________________________
fewer colds ______________________
fewer eye problems ________________
less coughing _____________________
fewer headaches __________________
other (specify) ___________________

46. If you had had to pay for the new smokeless chula, how much would you have been willing to pay? _______________

47. Do any of your family smoke?

Family member # smoked/day

Questions for oldest woman in the household

48. What kind of stove did you use when you were newly married? Was it of the same type as is seen in your kitchen today?

49. a) What kind of cooking fuel did you use in the past? Did you use more

Twigs _______________
Logs/branches ________
Crop residues ________
Other (specify) ______
No change ___________

b) Was fuel more easily available then? Yes/No
c) Was it
gathered ________
bought __________
from own sources _______

50. a) Has people's diet changed in any way? If yes, explain.
b) Has the method of cooking changed in any way. If yes, explain.

APPENDIX B

AIR POLLUTION MONITORING DATA SHEET

Household no. Household code.

Name of cook: Age: Relship. to head of hhld.:

Date: Time: No. of people at meal:

Stove type:
Location:

Fuel type:
Quantity (wt.) at start: At finish:
Wt. of charcoal:

Type of food being cooked:
Estimate quantity:

Wind speed:
Anemometer on: Anemometer off: Reading:

Temperature:
Begin: Finish:

Relative humidity:
Begin: Finish:

Personal monitoring:
Gilian start time:

Gilian filter no. Weighti Weightf

Gilian stop time: Gilian flow rate: Obs. Corr.

Passive monitoring:
Miniram start time:

Miniram stop time: TWA:

Remarks

CO readings

Household no.: Household code:

Date: Time: Cook:

Time	Reading/Remarks	Time	Reading/Remarks

NOTES

1. In parts of northern India, ambient TSP levels can be quite high during winter months when temperature inversions often trap pollutants. In these circumstances, the ambient exposures and the influence of ambient concentrations on indoor air quality can be significant (Smith and Durgaprasad, 1987).

2. This decision turned out to have its disadvantages as it leaves the filter paper unprotected and vulnerable. More that once a monitoring session had to be repeated because the filter paper was contaminated during the session. This usually happened when the cook picked up a child to comfort and the child took the opportunity to investigate the filter cassette more closely.

3. Since the current national program grew out of the National Project on the Demonstration of Improved Cookstoves, and most of the information available relates to the National Program on Improved Cookstoves, the dissemination program in Garhibazidpur will be discussed as being part of the current national program. Where the National Program on Improved Stoves differs substantially from the National Project on the Demonstration of Improved Cookstoves, the departure will be pointed out.

GLOSSARY OF HINDI AND KANNADA TERMS

Agena	Open fires (Nepal)
Bajra	Millet
Chula	Enclosed fireplace (Nepal); Hindi term for traditional stove (India)
Chula mistri	Stove builder
Ghee	Clarified butter
Guar	Cymopsis tetragonoloba
Hara	Type of stove used for slow cooking (Haryana)
Keekar	Acacia nilotica
Khathi	Carpenter
Lassi	Diluted yogurt
Neem	Azadirachta indica
Ole	Kannada term for stove
Ragi	Eleusine coracana; millet
Roti	Unleavened bread
Sambar	Curry
Sarson	Mustard
Subzi	Vegetable dish
Tava	Metal griddle
Til	Sesame

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