1

Introduction

1.1 Exposure to indoor air pollution (IAP) can be attributed to two principal sources. Traditionally, the most important source of exposure to indoor air pollution has been from cooking and household heating using solid fuels such as firewood, coal, manure and agricultural wastes. In developed countries, environmental tobacco smoke (ETS) has been identified as a principal modern day source of exposure to indoor air pollution.

1.2 Recognition of the problem of indoor air pollution and its deleterious effects on health is one that is gaining increasing prominence worldwide through increasing efforts to understand and articulate the complex health-air pollution linkages, as well as address health impacts. Half of the world's population is exposed to indoor air pollution, mainly from burning solid fuels for cooking and heating. Evidence of association between biomass fuel combustion and incidence of chronic bronchitis in women and acute respiratory infections in children has been documented. Some of the relevant references are cited in later sections of this report.

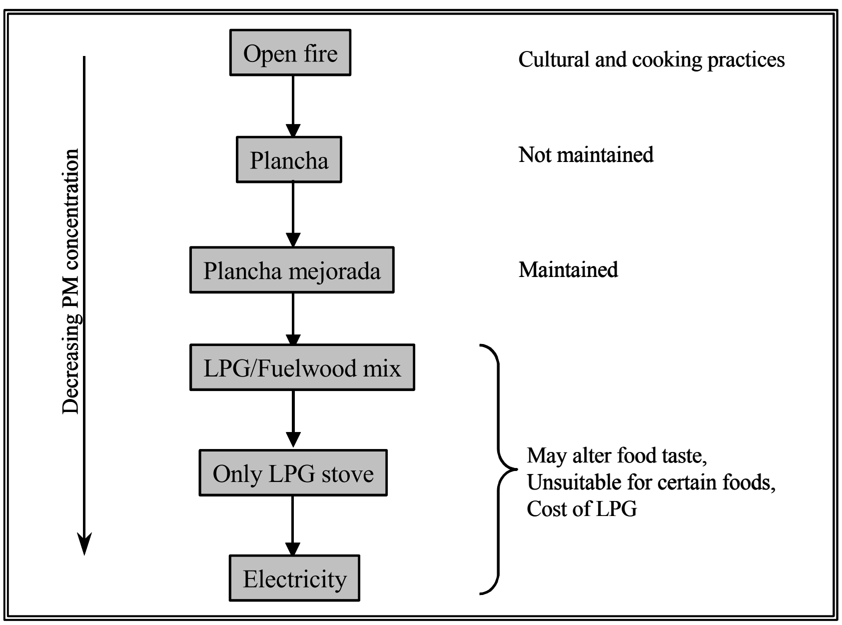
1.3 A World Health Organization (2002) report concluded that consistent evidence exists that exposure to biomass smoke increases the risk of a range of common and serious diseases in both children and adults. Most notable among these diseases are acute lower respiratory infections (ALRI)[1] in childhood, and in particular, pneumonia. The report also identified indoor air pollution from solid fuels as one of the 10 leading selected risk factors responsible for a substantial proportion of leading causes of death and disability. It is estimated that indoor smoke from solid fuels causes 1.6 million deaths annually and accounts for 2.7% of the global burden of disease. Furthermore global estimates attribute 36% of all lower respiratory infections, 22% of chronic obstructive

[1] Acute Respiratory Infection, ARI, may comprise lower respiratory tract infections (ALRI) or upper respiratory tract infections (URI).

pulmonary disease (COPD), and 1.5% of trachea, bronchus and lung cancer to indoor air pollution.

1.4 In rural areas especially, burning traditional fuels in ill-designed stoves or hearths exposes women and children to harmful concentrations of particulate matter and gaseous pollutants and causes damage particularly to the health of women who typically spend considerable amounts of time cooking, and young children who spend time around the women. The World Bank's Environment Strategy for the Energy Sector (1999) estimated that, in developing countries, nearly 60% of premature deaths caused by local air pollution are those of children under the age of 5 as a result of exposure to dirty cooking fuels. Globally, in high mortality developing countries it is estimated that 3.7% (DALYs)[2] of the burden of disease is caused by indoor smoke from solid fuels. In high mortality countries in the Americas - typically in Latin America - it is estimated that indoor smoke from solid fuels causes 10,000 deaths and 298,000 years of life lost annually (WHO, 2002).

Figure 1.1: Energy options with increasing mitigation effectiveness for health impacts of IAP



PM = Particulate Matter

[2] DALYs or disability-adjusted life years are a standard metric of the burden of disease. DALYs combine life years lost as a result of illness and disability; one DALY being equal to the loss of one healthy life year (Murray et al., 1996).

1.5 The literature and experience from various countries indicate that mitigation of the health impacts of indoor air pollution can be achieved through moving up the energy ladder, by households switching from using wood to cleaner, liquid or gaseous fuels, such as kerosene and liquefied petroleum gas (LPG), and eventually electricity. At the lower end of the energy ladder, better ventilation and adoption of improved biomass stoves, which vent smoke through a chimney from the cooking area in households, are technical options for decreasing emissions of harmful pollutants. Fig.1.1 illustrates these different fuel and technology options. Clearly, policy options that would facilitate the penetration of these options are cross-sectoral, and include fuel pricing and distribution policies, small business development, income generation activities and health education. It should also be noted that behavioral and cultural factors are equally important when considering technical mitigation options, and are often the greater barriers that need to be addressed, together with lack of information barriers, to achieve positive health impacts.

Nature of the problem in Guatemala

1.6 ***ALRI and Exposure Monitoring in Guatemala.*** Recent statistics (Table 1.1) from the *Ministerio de Salud Publica y Asistencia Social (MSPAS)* in Guatemala indicate that between 1997 and 2000, Acute Respiratory Infection (ARI) was the single most important cause of morbidity and mortality in Guatemala.[3] In this period, the number of cases of morbidity due to ARI grew by an average of 31% in the country.[4] In the same period, ARI caused on average 2-3 times as many deaths as acute diarrhea, the second most important cause of mortality in Guatemala.

1.7 As a subset of this data, the impact of ARI on the health of children in Guatemala is particularly important. In the period 1997-2000, pneumonia represented the most important single cause of infant death in Guatemala and accounted for 36% of all registered deaths amongst infants in 2000.

1.8 Notwithstanding the adverse health impacts of IAP, in the Latin American (LAC) region, with the exception of a few concerted individual efforts, activities directed to studying and addressing indoor air pollution in the region have been relatively limited. In Guatemala, however, various studies have been conducted on several aspects of the health impacts of indoor air pollution, including studies that measure indoor air pollution concentrations associated with various types of fuel (Smith *et al*., 1993, 2000; McCracken *et al*., 1998 among others).

---

[3] See footnote 2.

[4] See footnote 3.

Table 1.1: Five principal causes of general morbidity and mortality in Guatemala between 1997 and 2000

Morbidity (per 1,000 habitants)	**1997**	**1998**	**1999**	**2000**
ARI	**54.0**	**70.2**	**103.3**	**118.7**
Intestinal parasites	23.6	34.5	39.2	44.5
Acute diarrhea	17.0	28.2	31.1	45.1
Pneumonia and bronchial pneumonia	14.8	20.4	23.0	21.6
Anaemia	8.8	11.7	19.6	29.1
Mortality (per 10,000 habitants)				
Pneumonias	**10.5**	**11.2**	**10.8**	**9.6**
Acute diarrhea	4.2	5.6	2.9	3.6
Malnutrition	1.6	1.5	1.6	1.5
Cancer	1.5	1.5	1.5	1.5
Acute heart attack	1.8	1.2	1.5	2.0

Source: Ministerio de Salud Publica y Asistencia Social, Guatemala

1.9 In order to better understand the associations - including the exposure-response relationships - between particulate pollution from biomass fuel cooking and health, the WHO in 1992 established a committee, to examine the feasibility of conducting controlled intervention studies designed to assess the effects on key child and adult respiratory health outcomes of a measured reduction in exposure. Pursuant to a set of epidemiological studies to determine the risk-reduction potentials of various interventions (e.g. fuel substitution, stove alteration, ventilation provision, and behavioral modification), the WHO sponsored several pilot studies in the western highlands of Guatemala (Bruce et al., 1998; McCracken and Smith, 1998; Neufeld, 1995; Smith et al., 1993). Some of these studies and their findings are described below.

1.10 Bruce et al., (1998) examined the association between respiratory symptoms and the use of open fires and improved wood-burning stoves with chimney (or *planchas*) in a cross-sectional study of 340 women aged 15-45 years living in a poor, rural area in the Western highlands of Guatemala. This study used direct measures of exposure and sought to address the aspect of confounding by systematically examining the extent to which strong associations with confounding variables in the studies settings limited the ability of observational studies to define the effect of indoor air pollution adequately. The study found that the prevalence of reported cough and phlegm was significantly higher for three or six symptom measures among women using open fires. Furthermore, very strong associations were found between the type of fire (open fire or *plancha*) and a number of household and socioeconomic factors including the arrangement of rooms, floor type, and possession of a radio and television. This study concluded that although there existed a reasonable case for a causal association, confounding presented a substantial problem for observational studies of indoor air pollution and health, and therefore intervention studies were required to demonstrate stronger evidence for the association, and, more importantly, to determine the magnitude of the health benefit achievable through feasible exposure reductions.

1.11 Other studies, such as that of McCracken et al. (1998), compared the thermal efficiency and emissions of the traditional three-stone fire and the *plancha*. The study reported that no statistical difference in efficiency between the *plancha* and traditional stove was found. However, the *plancha* emitted significantly less suspended particles and carbon monoxide (CO) compared to the open fire.

1.12 Further work has included a number of studies related to exposure assessment in the western Guatemalan highlands. Naeher et al., (2000a) conducted a study to determine if the indoor air pollution levels in a number of villages in the western Guatemala highlands made them viable for an intervention study. These workers monitored $PM_{2.5}$ and CO during breakfast, lunch and dinner in three high-density and four low-density villages. The study also investigated the impact of "neighbourhood" pollution on indoor levels as well and characterized indoor concentrations for different meals and stoves. It was reported that although the predominant stove type was the open fire, several other stoves in various levels of disrepair were observed frequently. The highest concentrations of $PM_{2.5}$ were observed in homes using the open fire (avg. = 5.31mg/m^3) or equivalent, although homes using the *plancha* also recorded measurements over 13.8mg/m^3. Similarly, the highest indoor concentrations of CO were observed in homes using open fires (avg. 22.9ppm) with a maximum measurement of over 250ppm. Levels of $PM_{2.5}$ and CO measured in homes with the *plancha*, lorena stove or open fire were significantly higher than levels taken in the street or in homes using a gas stove. The findings of the study demonstrated a significant difference in indoor concentrations between stove types during cooking times. Thus from an exposure-based assessment perspective, the study concluded that the studied region was a viable area in which to conduct an epidemiological intervention study aimed at investigating the association between biomass fuel combustion and ARI and other health effects in women and children. In addition, the variation of indoor levels of $PM_{2.5}$ and CO in homes with *planchas* demonstrated that some *planchas* produce indoor levels intermediate between gas stoves and open fires, suggesting the need for more intensive monitoring of exposures in households with *planchas*.

1.13 In another study, Naeher et al., (2000b) examined the effectiveness of a range of intervention stoves in reducing indoor air pollution. They studied indoor and outdoor pollution levels notably, particulate matter and carbon monoxide, from traditional and improved wood stoves and gas stoves, taking measurements in kitchens, bedrooms and outdoors in three test homes before and after introduction of potential exposure-reducing interventions. With nine observations, these studies found that kitchen $PM_{2.5}$, PM_{10} and CO levels for open fire conditions were consistently higher than for the *plancha* and gas stove conditions. With nine observations each, kitchen $PM_{2.5}$ levels were 56 μg/m^3 under background conditions, 528 μg/m^3 for open fire conditions, 96 μg/m^3 for *plancha* conditions and 57 μg/m^3 for gas stove conditions. Corresponding PM_{10}/TSP[5] levels were 173/174, 717/836, 210/276, 186/218 μg/m^3. Corresponding CO levels were 0.2, 5.9, 1.4 and 1.2ppm. Table 1.2 presents these findings. Comparisons with other studies in the area indicated that reductions in indoor concentrations achieved by improved wood-burning stoves deteriorate with stove age. These authors showed that improved wood stoves with flues and gas stoves reduce exposures to 10 to 20% of those observed in kitchens using open fires for cooking.

Table 1.2: Comparison of emissions from open fire, *plancha* and LPG stove in Guatemala highlands (Naeher et al., 2000b)

Type of stove	Pollutant (concentration)		
	$PM_{2.5}$ (μg/m^3)	**PM_{10}** (μg/m^3)	**CO** (mg/m^3)
Open fire	527 ± 248.5	717 ± 284.6	5.9
Plancha	96.5 ± 66.5	186.3 ± 89.5	1.4
LPG stove	56.8 ± 19.0	210.2 ±100.3	1.2

$PM_{2.5}$ and PM_{10} = Continuous particles less than 2.5μm and 10 μm in diameter respectively. Results are average ± standard deviation

1.14 While particulate matter would provide the best indicator of pollutant risks from fuel combustion for planned studies of childhood ARI, unfortunately, the large scale, long duration, and difficult logistics of such studies make the widespread use of particulate monitoring equipment problematic and expensive. Naeher et al., (2001) investigated efficient and effective $PM_{2.5}$ measurements and examined how personal measurements relate to area measurements. The study showed that CO is a strong proxy for $PM_{2.5}$ exposure in homes using open fires or *planchas* but its use as a proxy is not valid under gas stove use or similarly clean burning conditions. This finding was in agreement with the reports of McCracken et al. (1998). Secondly the study reported that the mother's personal CO exposure is strongly correlated with the child's (less than 2 years of age) personal CO exposure, suggesting that mother personal CO exposure monitoring can be used as a proxy for child's CO exposure monitoring. In addition, the study demonstrated that area CO measurements were not representative of personal CO measurements.

1.15 Albalak et al. (2001) conducted studies of measurements of indoor respirable particulate matter concentrations from an open fire, *plancha*, and LPG/open fire combination in a rural Guatemalan community. These studies were conducted in 30 households and compared $PM_{3.5}$ concentrations over 8 months for each situation. The study reported a 45% reduction in $PM_{3.5}$ concentrations for the LPG/open fire combination as compared to the open fire alone. The *plancha* showed an 85% reduction

[5] Total Suspended Particles

in $PM_{3.5}$ concentrations compared to the open fire. The reduced $PM_{3.5}$ concentrations were not affected by time or season.

1.16 Emerging from the background of pilot and other studies that have been conducted in Guatemala, is a recently initiated intervention study, financed by the U.S. National Institutes of Health, which is being conducted by Kirk Smith and colleagues in the Guatemalan highlands, specifically the San Marcos area. Some of the studies described above were included in the feasibility studies that were used to design the intervention study. The study is expected to last two years, and hopes to achieve the following: (i) reduction or elimination of the confusing variables in the IAP-health nexus through random design selection; (ii) quantification of risks to permit direct measurements of exposure; (iii) standard definition of cases and thorough confirmation of cases in the community; and (iv) direct proof of the effect on health of an accepted and practical intervention in the area.

1.17 ***The Country Context.*** The preceding section describes how ARI and pneumonia are the top causes of morbidity and mortality in Guatemala, and the work underway to show the extent of linkage between these and IAP. Equally important, however, is the country context and the close linkage between IAP and poverty, levels of rural electrification and traditional fuel use. In Guatemala, IAP arises from burning firewood, typically utilizing a three-stone fire. It is usually the rural poor, who are disproportionately affected as they have no alternative, since they are not connected with the electricity grid, or cannot afford cleaner fuels. The recently completed Guatemala Poverty Assessment (2003) provides the following country-level data on these factors:

(i) **high incidence of poverty**. In the year 2000, over half of all Guatemalans – 56% or about 6.4 million people – lived in poverty, and more so at a level higher that suggests that poverty is higher than in other Central American countries, despite its mid-range ranking using per capita GDP.

(ii) **low levels of rural electrification**. Access to modern utility services is highly inequitable. While access to electricity among other utilities are almost universal in coverage in urban areas, they reach little more than half of rural households. Less than 40% of the poorest households have electricity connections compared to 95% of the richest households.

(iii) **Large rural populations**. Over 60% of the Guatemalan population live in rural areas, and the remaining 40% in urban areas. Poverty in Guatemala is predominantly rural and extreme[6] poverty is almost exclusively rural. 81% of the poor and 93% of the extreme poor live in the countryside. Three quarters of all rural residents fall below the full[7] poverty line and one quarter live in extreme poverty.

---

[6] Extreme poverty line is defined as yearly cost of a "food basket" that provides the minimum daily caloric requirement of 2,172 (World Bank, 2003 Guatemala Poverty Assessment).

[7] Full poverty line is defined as the extreme poverty line (the cost of food that satisfies the minimum caloric requirement) plus an allowance for non-food items (World Bank, 2003 Guatemala Poverty Assessment).

(iv) **High levels of traditional fuel use**. In Guatemala, fuelwood is the dominant cooking fuel in 97% of households in rural areas. Furthermore, 42% of rural households use fuelwood only while 55% practice multiple fuel use, whereby the household uses more than one type of fuel.

1.18 The Guatemala Poverty Assessment (2003) also identifies five priority groups to which poverty reduction efforts should be targeted. They are as follows: (i) poor and malnourished children (especially age groups 0-6 years, and 7-13 years), (ii) poor girls and women, (iii) poor indigenous households, (iv) rural poor and (v) specific geographic areas notably in the "poverty belt" i.e. the northern and north-western regions as well as the department of San Marcos.

1.19 In the rural Guatemalan highlands, approximately 400,000 children under the age of 5 years live in homes where open fires are used for cooking. The risks of ARI are increased by poverty, inadequate dwellings, overcrowding, malnutrition, deficiency of micronutrients, indoor and outdoor air pollution and environmental tobacco smoke. These findings underscore the strategic importance and timeliness of a study to better understand the impact of indoor air pollution on the health of vulnerable groups among poor rural populations in Guatemala, as well as the policy options for mitigating any impacts.

Context for this report

1.20 The completion of this report represents the final activity in a series that have focused on examining the problem of indoor air pollution and its impacts on health in rural households in Guatemala; and disseminating the findings. The study was carried out between October 2001 and June 2003, with support from the joint UNDP/World Bank Energy Sector Management Assistance Programme (ESMAP). This report summarizes the findings of each of a series of sub-studies and two workshops, and presents final recommendations.

1.21 The objectives of this study were to (i) estimate the health impacts of traditional fuel use; and (ii) outline strategies and policies for mitigating environmental health damages from household energy. Mitigation of indoor air pollution due to the use of traditional biomass fuels has been identified in the World Bank's Environmental Strategy for the energy sector, *Fuel for Thought*, as a high priority. In addition, given the close linkages between IAP and women's and children's health, this study provides relevant information for the Government with respect to achievement of the Millennium Development Goals (MDGs) to (i) reduce child mortality in Guatemala, and (ii) improve maternal health.

1.22 This study is the first of its type conducted by the World Bank in the Latin America Region. It is in response to a request by the Ministry of Energy and Mines. The rich source of data on the subject of indoor air pollution and health, some of which were cited in the preceding section; the close linkage between IAP and poverty, described above; and the potential replicability, in terms of applying lessons learned through this work in other Central American countries faced with similar issues, were also important considerations in carrying out this study.

Individual studies

1.23 The major activities carried out under the study included individual studies of specific aspects of the indoor air pollution and health matrix, as well as two dissemination workshops. The specific studies carried out under the overall study are listed below and are described in more detail in the body of the report:

(i) a review of the existing literature on indoor air pollution and health globally and in Guatemala, and an estimate of the health implications of not addressing the problem of acute respiratory infections (ARI) and IAP either through policy interventions or technical mitigation measures;

(ii) a review of two major surveys conducted in Guatemala: the 1998-1999 Demographic Health Survey (DHS), and the 2000 Living Standards Measurement Survey (LSMS) in order to investigate potential relationships between energy use and indoor air pollution;

(iii) an evaluation of improved stoves programs in Guatemala, and a focused review of the cost structure of stoves under such programs; and

(iv) a study of the LPG industry and market in Guatemala.

1.24 These activities were chosen to specifically complement existing activities underway in Guatemala at the time, including a Poverty Assessment, financed by the Bank; an ESMAP-sponsored network in Central America on Women and Improved Stoves; and exposure monitoring through an intervention study financed by the U.S. National Institutes of Health. In addition, at the time of the study, the Bank and other development partners were providing support to the Social Investment Fund (*Fondo de Inversion Social*, FIS), which included, as one component in a menu of poverty reduction actions, the largest improved stoves program in Guatemala. Therefore a particular focus of this study included a review and corresponding policy recommendations to enhance the impact of this particular program, with respect to reducing indoor air pollution.

1.25 It is worth noting that this study is, by no means, comprehensive. Future areas of investigation include (i) a better understanding of the changes in exposure to PM 2.5 of different members of the household when using an improved stove under real conditions (with a focus on both operation and maintenance of the stove) and the corresponding impact on health; (ii) an analysis of the costs and benefits of different mitigation options; (iii) an analysis of LPG availability and corresponding issues in the rural areas; and (iv) assessing current and planned rural development programs and providing recommendations (based on worldwide experience) on how best to integrate technical options for mitigating indoor air pollution in the context of these programs.

Structure of the Report

1.26 Following this introduction, Chapter 2-5 describe the findings and recommendations of the four individual studies listed above. In particular, Chapter 2 presents the results of an exploratory study based on two large household surveys conducted during the last 5 years, attempting to examine any linkages between energy use and health. Chapter 3 presents a review of exposure monitoring studies in Guatemala, and attempts to carry out some back-of-the-envelope type estimates (based on worldwide IAP health studies) of the health implications of not addressing the problem of acute respiratory infections (ARI) and IAP either through policy interventions or technical mitigation measures. Chapter 4 examines and learns from one of the most active stove programs in Central America. Chapter 5 assesses the LPG market in Guatemala to gain a better understanding of some of the current and potential future problems that might discourage households from using LPG. Finally, Chapter 6 summarizes policy recommendations, incorporating feedback from the two workshops, and emphasizes the need for a multisectoral approach in order to address this issue which is so closely linked with the MDGs and Guatemala's development.