School of Public Health

Indoor Air Quality, House Characteristics and Respiratory Symptoms among Mothers and Children in Tamil Nadu State, India

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Declaration

This research was conducted in Tamil Nadu (data collection) in South India and Western Australia. This thesis addresses indoor air quality, social and economical factors, house characteristics and respiratory symptoms among mothers and children from Tamil Nadu State in South India.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of my knowledge and belief, it contains no material previously published by any other person except where due acknowledgment has been made.

Signature:
(M D Kandiah)
Date:22/09/2010

“The knowledge that you have gained at school will be valueless unless you retain it and strengthen it and increase it”- John Curtin (07/01/1908)

“The more I learned about the field, the more I realized how little I know about it”

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ABSTRACT

Air pollution is a problem affecting developing and developed countries concerned about the adverse health effects associated with exposure to indoor and outdoor air pollutants. In developing countries like India, the problem, particularly domestic air pollution, is worsened by the use of unprocessed solid fuels for cooking. Other indoor environmental risk factors include the characteristics of housing conditions, household activities, and low Socio-economic status (SES). The potential irritants include nitrogen dioxide (NO_2), formaldehyde (HCHO), volatile organic compounds (VOCs), indoor smoking, and particulate matter ($PM_{2.5\text{-}10}$) and carbon monoxide (CO).

Indoor air pollutants, especially those in domestic households are major problems that can contribute to respiratory symptoms and poor health in mothers and children and, in particular, those who live in poorer households in developing countries. There is consistent evidence that mothers and young children from these countries spend more than 80% of their time indoors, especially in the kitchen. Therefore, domestic air quality may be related to the increase in the prevalence of respiratory symptoms and other allergic conditions. In this context, this study established risk factors in the domestic environment that can determine the concentrations of domestic air pollutants and prevalence of respiratory symptoms in mothers and children. Cooking for a long time, keeping young children and infants in cooking areas, the inadequacy of ventilation, and the use of biomass fuels can relate to debilitating health problems, especially respiratory symptoms among poor households' mothers and children particularly in developing countries.

This study is cross-sectional and aims to determine that domestic concentrations of fine particles ($PM_{2.5}$), carbon monoxide (CO), and the socio-economic status (SES) and/or poverty levels, house and kitchen characteristics and households' activities, may have a detrimental role in the prevalence of respiratory symptoms among mothers and children. One hundred and seventy households (N=170) with young children (n=299) under 15-years-of-age were selected randomly from the City of Tirupur in Coimbatore district, Tamil Nadu in South India. This city was chosen as it has diversity in terms of its ethnic mix, economic activities, physical characteristics and income disparities. Each participating household was visited and 170 households' mothers were interviewed using a questionnaire. During the visits, study data was also collected in 80 households by measuring of indoor concentrations of $PM_{2.5,}$ CO and the physical parameters, humidity and temperature.

According to the statistical analysis, using biomass for cooking affects mothers' and children's respiratory symptoms. The results of this study show that median exposure to fine particles ($PM_{2.5}$) ($1.18 mg/m^3$) exceeds the recommended WHO standards. CO concentrations did not have any significant relationship with mothers' and children's respiratory symptoms as mean concentrations of CO were 4.63ppm or $8.80 mg/m^3$. The study shows that kitchens with brick/stone walls and tile roofs are associated with reduced concentrations of $PM_{2.5}$ (p=0.033). If a kitchen has mud walls, a thatched roof and a floor of clay/mud, the indoor air has higher concentrations of $PM_{2.5}$ (p=0.014), Floors, such as cement, can lower the domestic air concentration of $PM_{2.5,}$ (p=0.014). The study finds that lower concentrations of $PM_{2.5}$ were also found when windows were open (OR=0.14), (p=0.018).

The study shows that there is a significant relationship between the prevalence of asthma in children in relation to CO and more than one time (OR=1.19) with p=0.021. In this study, it was shown that mothers with lower incomes had shortness of breath (p=0.003), almost six times higher than mothers with higher incomes. Children with allergies (78.9%) in the current study came from families where the mothers were employed as labourers and their children had respiratory symptoms such as coughing (p=0.001) and wheezing (p=0.002). The most (p=0.001) significant respiratory symptom of children from families who did not own house/unit or land was a cough: 56 (42.4%) as they usually live either in semi-open air or very badly constructed dwellings).

High R/H (%) and T^{o}C also seem to have an effect on domestic concentrations of PM$_{2.5.}$ As revealed by the statistical analysis, high T^{o}C and RH (%) were associated with significant impacts on mothers' respiratory symptoms but did not have any significant impact on children's respiratory symptoms. High-income households' mothers and children were seen to have less significant respiratory symptoms than low-income households' mothers. Evaluation of the literature also assessed the extent to which SES and/or poverty levels and house and kitchen characteristics and households' activities affected respiratory symptoms in mothers and children.

In conclusion, this study's results further highlight the role of susceptibility risk factors for respiratory symptoms and show that domestic environmental factors contribute as risk factors for respiratory symptoms in mothers and children, especially in poor households. In order to improve domestic air quality and thus decrease the prevalence of respiratory symptoms, much more effort needs to be made. Because the air quality in the domestic environment is modifiable, there may be opportunities for intervention to reduce respiratory symptoms and this needs greater attention. Low SES and/or poverty levels may cause greater susceptibility to disease through malnutrition, access to health care, better housing and children's and adult education.

This study also provides recommendations how to reduce the prevalence of respiratory symptoms by improving households' SES and/or poverty levels, one of the main risk factors for adverse health effects of respiratory symptoms in mothers and children from Tamil Nadu, South India. Since the quality of the domestic environment is very important, further intervention is needed to reduce respiratory symptoms in mothers and children, particularly young ones at a time when immune deviation usually occurs, regarding where they grow and spend most of their time. Finally, in order to reduce indoor air pollutants and respiratory symptoms in mothers and children, much more effort and greater attention needs to be paid to improve households' low SES and/or poverty levels. The main goal should be sustainable development and poverty reduction that will enable people eventually to switch to clean fuels. SES was the most significant predicator of cooking fuel choice to ensure good health.

DEFINITIONS OF TERMS USED

Acute illness - a brief but serious episode of illness (Mauskar, 2008);

Air pollutants- can be described as chemical, physical, or microbiological, such as particles, gases, fumes, vapours, mould, bacteria, viruses, and substances that can harm humans, animals, vegetation and material (Manins, 2001 & Witorsch and Spagnolo, 1994);

Air quality - the condition of the air we breathe. Indoor air quality is the nature of the air that affects the health and well-being of occupants (Junction and Rish, 1997; NPI, 1999);

Allergy - An altered or exaggerated susceptibility to various foreign substances, which are harmless to the great majority of individuals. Asthma is an allergic condition (Mauskar, 2008);

Ambient air - The outdoor or surrounding air (NPI, 1999);

Aerosol - A depression of very small solid or liquid in a gas i.e., fog and smoke (NPI, 1999);

Any ever wheeze - “Has your child ever had wheezing or whistling in the chest at any time in the past” (Zhang, 2004, p213);

Association - The statistical dependence between two or more events, characteristics, or other variables (Last, 1988);

Bias - Deviation of results or references from the truth, or processes leading to such deviation (Last, 1995);

Bidi - Local cigar;

Biomass fuel - refers to any plant or animal based material deliberately burned by humans/ the total mass of living organisms present in an area, ecosystem, environment or in a category of organisms (WHO, 2002);

Caste (discrimination) - Caste is descent-based and hereditary in nature. It denotes a system of rigid social stratification into ranked groups defined by descent and occupation (United Nations, (UN) 2001);

Chronic obstructive pulmonary disease - Progressive damage of the lungs usually leading to shortness of breath and wheezing (often means chronic bronchitis and emphysema). (Mauskar, 2008);

Chulha -Traditional biomass stove with three stones (Kanagawa and Nakata, 2004);

Confounder - A factor or variable that can potentially cause or prevent the outcome or disease being studied (the dependent variable), and must be taken into account or it will prevent reaching a conclusion regarding the impact of the *independent variable*, or hypothesized cause of the outcome of the disease being investigated (Mauskar, 2008, p201);

95% Confidence Interval - The statistically determined, upper – and lower – bound with a 95% chance that a measurement will occur within these upper and lower values (Gordis, 2000);

Cross-sectional study - A study of the relationship between diseases with other variables of interest in a defined population at a particular point of time (Mauskar, 2008, p.202);

Dalits - So-called untouchables (low caste people) from South Asia-including Nepal, Bangladesh, Sri Lanka, India, Pakistan, the Buraku people of Japan and the Osu of Nigeria's Igbo people and certain groups in Senegal and Mauritania (UN, 2001);

Dosage - The dosage of a pollutant is the amount of pollutant that goes into the body through ingestion, inhalation or dermal absorption (Sexton & Ryan, 1988);

Effect modifier - A factor that modifies the effect of a putative factor under study (Last, 1988);

Exacerbate - To aggravate or make asthma worse. “Exacerbate” replaces the word “cause”, induce” (Rumchev, 2001);

Exposure - Proximity and/or contact with a source of a disease agent in such a manner that effective transmission of the agent or harmful effects of the disease may occur (Last, 1988);

Fossil fuels - Fuels derived from fossilised organic matter such as coal, oil and petroleum (NPI, 1999);

Hazard - A factor or exposure that may adversely affect health (Last, 1988);

Hill’s Criteria - Hill’s Criteria of Causation outlines the minimal conditions needed to establish a causal relationship between two items;

Immunity - An individual’s resistance to infection. Resistance to a disease by the host may be natural, passive or acquired (Mauskar, 2008);

Incidence - The number of individuals who develop an abnormality within a given time usually a year, expressed as a percentage of the population (Toelle, 1992);

Morbidity - The degree to which quality of life is impaired (Toelle, 1992);

Odds ratio - Use of odds ratios to compare risks in different groups;

Particulate matter - Particles of solid or liquid matter in the air, including non-toxic materials (soot, dust, dirt), heavy metals (e.g., lead), and toxic materials (as asbestos, suspended sulfates, nitrates) (Mauskar, 2008, p.205);

$PM_{2.5}$ - Particulate matter less than 2.5 μ m aerodynamic diameter (Mauskar, 2008);

Pollutant - Any substance that renders the atmosphere or water foul or noxious
or a health hazard (Mauskar, 2008);

Respirable particles - Particles which can penetrate to the unciliated regions of the lung (Mauskar, 2008);

Prevalence - Prevalence is the condition of being prevalent. The proportion of the population with a disease, disorder, or abnormality (Toelle, 1992);

Reliability - concerns the extent that repeat measurements made under constant conditions will give the same result (Moser, 1986);

Respirable particle - Particles smaller than 10 microns, (PM_{10}) most likely to be deposited in the pulmonary portion of the respiratory tract (Mauskar, 2007);

Respiratory tract - Body structures used for breathing including the mouth, nose, throat and lungs (NPI, 1999);

Risk factor - An aspect of personal behaviour or lifestyle attribute or exposure that is associated with an increase or decrease in the probability of the outcome (Last, 1988);

Thatch - Straw, reeds, rushes and coconut leaves (very common in India), etc, used for covering the walls and roofs of houses (Mauskar, 2008);

Socioeconomic status (SES) - refers to an individual's relative position in the social hierarchy and can be operationalsed as level of education, occupation and /or income (Mackenbach and Kunst, 1997);

Social gradient in health - People's living conditions and the environment in which they live and work can influence their health (WHO, 2003);

Smog - A term often used to describe a mixture of smoke and fog. Also used to describe photochemical air pollution, or smoky fog, the word is used loosely to describe visible air pollution (Mauskar, 2008, p.207);

Smoke - Particulate matter, <15μm diameter, derived from the incomplete combustion of fuels, or an aerosol that is usually produced by combustion or the decomposition process (Mauskar, 2008, p.207);

Susceptible - A person with insufficient resistance or with associated risk factors to a particular pathogenic agent or process, so that there is a real danger of him/her contracting the specific disease, if or when exposed to the agent (Mauskar, 2008, p.207);

Symptom - An organic or physiological manifestation of a disease of which the patient is usually aware and complains of (Mauskar, 2008);

Total suspended particulate matter - A term describing the gravimetrically determined mass loading of airborne particles, most commonly associated with use of the US high volume air sampler in which particles are collected to filter for weighing (Mauskar, 2007);

Validity - concerns the extent to which an instrument measures what it is intended to be measured (Rothney, 1996).

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ABBREVIATIONS USED

ARIs	Acute respiratory infections
ATS	American Thoracic Society
BMI	Body mass index
BMRC	British Medical Research Council
COPD	Chronic obstructive pulmonary disease
CO	Carbon monoxide
CPCB	Central Pollution Control Board
95% CI 95%	Confidence interval
CVD	Cardiovascular disease
et al.	And others
DALY	Disability-Adjusted Life Years
ETS	Environmental tobacco smoke
IAQ	Indoor air quality
IAP	Indoor air pollution
LPG	Liquid petroleum gas
LRS	Lower respiratory symptoms
LRTIs	Lower respiratory tract infections
NAAQS	National ambient air quality standards
NEPM	The National Environment Protection Measure
NOx	Oxides of nitrogen
O_3	Ozone
OR	Odds ratio
PM	Particulate matter
PM_{10}	Particulate matter less than 10 μm in diameter
$PM_{2.5}$	Particulate matter less than 2.5 μm in diameter
PM_1	Particulate matter less than 1 μm in diameter
RS	Respiratory symptom
RSPM	Respiratory suspended particulate matter
SD	Standard deviation of mean
SES	Socio-economic status
SPM	Suspended particulate matter
SPSS	Statistical Package for Social Sciences

UFP	Ultra fine particle with a diameter of less than 0.1µm
URS	Upper respiratory symptom
URTIs	Upper respiratory tract infections
US EPA	United States Environment Protection Agency
VOCs	Volatile organic compounds
WHO	World Health Organization
WRI	World Resource Institute

CHAPTER ONE

INTRODUCTION

1.1 Air pollution

Air pollution is not a new phenomenon. Humans first might have experienced harm or felt sick from air pollution when they built fires in poorly-ventilated caves (Socha, 2007). Mummified lung tissue provides information on prehistory exposure to particulate matter in Egypt (after 1500 BC), caused by sandy wind and silica dust, from the cutting of stone. The United Kingdom (UK) has a very long history of environmental contamination: as far back as the 13th century. It was not until the 17th century that there was serious discussion of the association between poor air quality and disease. During the 17th century in the UK, chimneys were the first main pollution control measure when coal was used for cooking and winter heating. This early pollution was followed by the steam engine's noise, production of mortar and metalworking and smoke, mainly in the London area (Brimblecombe, 1999).

In 1880, 2,200 people died in London due to the toxic smog of sulphur dioxide gas and airborne particles from coal smoke from home-heating and industry (the World Resources Institute, the United Nations Environment Programme and the World Bank (WRI, UNEP & WB), 1999a & b). During the 20th century, the first known dramatic episodes of illness and death caused by poor air pollution occurred in the Meuse Valley, Belgium, in 1930, in London, England, in 1948, 1952 ("the London Fog") and 1956, in Donora, Pennsylvania, in 1948, in New York in 1953 and 1962, all of which were associated with deaths, primarily from pneumonia and cardiovascular disease. In 1984, in Bhopal, India, a chemical factory accident was one of the worst cases of pollution in the last century (Fry & Lond 1953; World Health Organization (WHO, 2004a; MfCA, 2006; Air pollution, 2006). In the latter part of the 20th century and the early part of the 21st century, the expanding use of fossil energy sources, the growth of manufacturing and use of chemicals contributed to increasing air pollution, so modern humans are exposed to air pollution in a number of different environmental settings (WHO, 2000a). Furthermore, poor air quality is largely and increasingly a consequence of human activities, such as the combustion of fossil fuel for transport, industry, power generation, coal use and firewood for space-heating, and biomass, which is a prime fuel for domestic use such as cooking, boiling water in poor and rural households in developing countries, including India.

Poor outdoor air problems cost millions of dollars and it has been estimated that, in Australia, it is costing the nation as much as A$12 billion a year, causing ill-health and lost production. Australia's wood smoke is a big indoor and outdoor problem. According to Environmental Australia (EA), (2003), in some areas, over 60% of households use wood for heating and open fireplaces. Indoor air pollution (IAP) is also very common in Western European countries and the USA (Demirbas, 2001). The US Environmental Protection Agency (USEPA) (1995), ranked IAP among the top five environmental risks to public health (Department of the Environment and Heritage, (DEH), 2004). In the UK, poor indoor air quality costs the economy US$30 billion a year. In India, environmental damage in 1992 cost US$10 billion (Environmental Protection Authority (EPA), 1999; Dewaram & Negdeve, 2002; World Resources Institute, (WRI), 2006). In 1985, the USEPA reported that in almost every USA home, indoor air is three times more likely to cause some type of cancer than outdoor air pollutants. The health problems in these homes or office buildings are called the "sick building syndrome". Indoor air in some US buildings is 100 times more polluted than outdoor air (Socha, 2007). According to Brown (2004) in Australia, the more significant indoor air pollutants are environmental tobacco smoke, respirable particulate matter, house dust mites, nitrogen, and volatile organic compounds, including formaldehyde. Air pollution is a significant health and environmental issue. Because of deteriorating indoor air quality, there is an increase in ill-health and premature deaths of millions of people (Holman, 1999; Emmanuel, 2004).

Globally, more than three billion people, mainly from developing countries, continue to use biomass (wood, animal dung, agricultural waste) and coal, for their energy needs such as for indoor or open fires for cooking, lighting, and/or space-heating (see Appendix M, Photo 1b), (Larson & Rosen, 2002; WHO, 2006b). Mothers and children (girls) collect 50% of the households' biomass fuel (see

Appendix l, Photos 1a, b & c). Biomass is used because of hardship or fuel or energy poverty “the relationship between energy and poverty is obvious and goes both ways” because when households are poor, they cannot afford clean fuel, due to high prices (called energy poverty) and vice versa when households are rich, they can afford to buy clean fuel for their domestic use (Pachauri, et al., 2005; Perera et al., 2005; Pronczuk de Garbino, 2005). Households can move from biomass fuel to cleaner fuels, a concept described in the so-called “energy ladder”. This ladder describes transitions in fuel use of different levels of economic development (Holden and Smith, 2000, p.3). For example, the use of animal dung is at the bottom of the ladder, further up is the use of crop residues, wood, charcoal, kerosene, liquid petroleum gas (LPG) and finally, at the top, electricity (see Appendix H, Figure 1a & b), (WHO, 2002; Smith, Mehta; Maeusezahl-Feuz, 2004). As shown by a WHO study, more than 2 million premature deaths per year are caused by indoor and outdoor air pollution, mainly from the burning of biomass fuel indoors and outdoors. In addition, levels of exposure are affected by cooking time, habits, activity patterns, literacy rate, family income levels, house and/or kitchen location and characteristics (Emmanuel, 2004). High concentrations of indoor pollution can result from the household use of biomass fuel instead of the use of clean(er) fuel, such as LPG, natural gas and electricity (Central Electricity Authority (CRA), 2005).

It is also now accepted that in developing countries, including India, the vast majority of human suffering and premature deaths is also poverty-related. The very low standards of living, sanitation, nutritional levels, overcrowding and inadequate or poor medical care, make people more susceptible to the effects of IAP (Viswanathan & Babu, 2000; Bagley, White and Golomb, 2001; MfCA, 2006). It is recognized that poor health effects are mainly caused by domestic smoke pollution (DSP), which is the fourth risk factor for the burden of disease, especially in these regions (WHO, 2005a).

1.2 Sources of indoor air pollution

Indoor air quality has been recognised as a major health, environment, and economic issue in many countries. Many studies have found that some air pollutants occur more than others and at a higher level indoors than outdoors, especially in a domestic environment, where households use biomass for indoor cooking (Brown, 2004, WHO, 2006b; Rumchev, Spickett and, Brown, 2007). IAP, particularly domestic air pollution, causes many health problems in both developed and developing countries because of the different types of polluting sources that release gases and particles into the indoor environment. IAP includes emissions from the combustion of biomass fuel, kerosene and oil for cooking, space-heating, lighting homes, boiling water, types of buildings, furnishing materials such as carpets, floor coverings, indoor activities, including hobbies and interests, products used for household cleaning and maintenance, tobacco-smoking and bidi-smoking in India. Outdoor air pollutants also influence indoor air quality. A study found that open fires are significantly associated with high concentrations of air pollutants (Bruce, Perez-Padilla and Albalak, 2002; WHO, 2002). Outdoor air pollution from power stations, road transport and cars, industry, and human activities can significantly influence indoor air quality (Holman, 1999; Saiyed, Patel and Gokni, 2001). Biomass fuel use and/or traditional cooking stoves, smoke (“chulha”) causes indoor air pollution, particularly domestic air pollution (Duflo et al., 2008).

1.3 Health effects associated with exposure to indoor air pollutants

Air quality has increasingly been attracting global attention because of adverse health effects associated with exposure to mainly indoor air pollutants. In many of the poorest parts of developing countries, one of the most insidious killers of the poor is indoor/domestic air pollution (WHO and United Nations Environment Programme (WHO and UNEP), 2007). Because of deteriorating indoor air quality, there is an increase in ill-health (Holman, 1999 and Emmanuel, 2004). This means households in these regions have a killer in the kitchen and it is (IAP) responsible for 1.6 million deaths and 2.7 million of the global burden of disease (EPA, 1999; WHO, 2002: WHO, 2006b; WHO, 2007c), (see Appendix L, Photos 2a, b & 3).

Approximately 40% of all children's deaths in developing countries are caused by exposure to IAP. Because their immune systems are still developing (Mauskar, 2008), they are particularly vulnerable to toxic effects of air pollution, mainly domestic air pollution, because of too great an indoor exposure. Children have a greater intake of air in relation to body weight, a lower breathing zone where particulate matter (PM) concentration is high and, most importantly, they have underdeveloped immunity (Mauskar, 2008). The main health effects associated with indoor air pollution are childhood mortality, (according to Mathur, (2001) acute respiratory infection (ARI) is the main cause of mortality in children aged less than 5 years) where more than half the deaths occur among children under five-years-of-age due to asthma, cancer of the asopharynx and larynx, tuberculosis, and prenatal mortality (WHO and UNEP, 2007c). Globally, it has been estimated that 3-5 million deaths occur annually in this age group and IAP is responsible for 0.8 million deaths in the adult population, per year, mainly women and mothers, from developing countries (WRI, 1998; WHO and UNEP, 2007). Indoor air pollutants are also major risk factors for pneumonia-related illness, low birth weight, chronic bronchitis in children, lung cancer, cataracts and cardiovascular disease in adults, and death (Steerenberg et al., 2001; WHO, 2004b; WHO, 2006b; Ayres, 2006).

A number of studies have related the above health effects to exposure to nitrogen oxide (NO_x), nitrogen dioxide (NO_2), carbon monoxide (CO), volatile organic compounds (VOCs), formaldehyde (HCHO), and particulate matter (PM) such as PM_{10} and $PM_{2.5.}$ Small particulate matter less than 2.5 microns in diameter is the most dangerous, ubiquitous, and complicated of air pollutants (WHO and UNEP, 2007; Massey et al., 2009). In developing countries, the most common health effects caused by IAP are children's respiratory problems, morbidity and mortality from households that use traditional biomass fuel. In India, 28% of all deaths are due to the use of biomass fuel, household economic status and unprocessed biomass fuel that typically releases at least 50 times more than the recommended WHO human exposure levels to pollutants other than LPG (Smith, 2000a; Saiyed, Patel and Gokani, 2001).

1.4 Socio-economic status and health effects

Socio-economic status (SES), is both economical and sociological, combined as a total measure of an individual's, household's, or family's economic and social position in relation to income, education, and employment or occupation (Gehring et al., 2006; WHO, 2008). The poverty gap is not just between developing and developed countries. Strong associations between SES and their factors can lead to greater access to resources and good health and well-being throughout people's whole lives. Clearly, socio-economic factors are fundamental elements of the causal pathways to poor health and disease that can have an impact on individual or family well-being (Li et al., 2008). In developing countries, most of the poor households' mothers and children are closely linked to low SES (Gehring et al., 2006). Income is a significant predictor of cooking fuel choice for low SES (World Bank Groups, (WBGs), 2004a & b; Andresen et al., 2005; Viseanathan & Kumar, 2005). It is estimated that every year, 44 million households globally face catastrophic health expenditure, which can be 40% of their total family income, and every year 25 million are forced into poverty as higher levels of out-of-pocket health expenditure cause them to become poorer (WHO, 2005a). The poorest of the poor have high levels of illness and premature mortality (WHO, 2008).

A number of studies have found higher rates of morbidity and mortality among groups with a lower SES, particularly mothers and children in developing countries (Ram, Hazra and Chakraborty, 2007; Health & Family Welfare Department (HFWD), 2007b; CIA-The World Fact Book, 2007; WHO, 2008). Households in India with lower SES and/or poverty levels also suffer from indoor environmental problems such as heat stress, lack of comfort, poor health, and poor IAQ (Santamouris et al., 2007). In addition, energy has numerous and complex links with poverty reduction (Kanagawa and Nakata, 2004) (see Appendix I, Figure 1c and 1d). Apparently, the SES and/or poverty levels of a family determine the decision to choose a particular source of energy (see Appendix H, Figure 1a). Rao and Reddy, (2005), found that for the selection of fuel per capita income, household size, educational status of the household, the head of the household's occupation, house location and its characteristics, may influence individuals’ or households’ SES and/or poverty levels.

The population most affected by poor indoor air quality and poor environmental conditions are poor households with low SES from peri-urban and rural areas in developing countries. As revealed by Kumar et al. (2008), there is evidence that (poorer households with lower SES) these may have greater susceptibility to disease; use more polluting fuels for their cooking; live in poorer housing; and have poor indoor, and outdoor environmental conditions. There is a positive relationship between household lower family income and pollutant emissions from the house (McLeod et al., 2000). “The social determinants of health are conditions in which people are born, grow, live, work and age, including the health system” (WHO, 2005-2008, p.1). Money, power and resources at international, national, local and even individual levels, which can be influenced by policy choice, cause these circumstances. It is mostly responsible for health inequities among poor households in developing countries, including India. In 2005, the WHO established a Commission on Social Determinants of Health (CSDH), with three recommendations, such as improvement of daily living conditions, equal distribution of money/wealth, resources, power and measures for understanding of the problem, and assessment of the impact of action. However, in developing countries, it is still evident there are huge and remediable differences in health between and within countries, and there are dramatic differences in mothers’ and children’s health that are closely associated with degrees of social disadvantage (WHO, 2008). Particularly in the developing countries and especially in India.

1.5 Statement of the problem

Most poor households in developing countries rely on biomass for cooking, boiling water, lighting homes, and space-heating. This fuel not only pollutes the domestic environment, but can also cause serious health problems because of indoor/domestic air pollution (Padma, 2009). No or little notice has been taken of the serious health effects, mostly on poor households’ mothers and children from these countries. The study by Balakrishnan, Ramaswamy and Sankar, (2005) argues that taking action to establish links between household fuel and occupants' health is an important strategy to improve the household environment and health. Due to the low standard of living in poor households in these countries, people can also suffer from nutritional deficiencies, poor sanitation, overcrowding, poor or inadequate medical services and health care. Private medical treatment is too expensive for the poor. The incidence rates of diseases such as tuberculosis and respiratory symptoms among mothers and children are high in developing countries, including India (Schwella, 1998; WHO, 2000d; WHO 2005a). Almost all previous studies on human health and indoor environments concentrate on exposure to indoor air pollution, without having considered the family's SES and/or poverty levels (see Appendix D, Figure 1 & Appendix E, Figure 1).

1.6 The aim of the study

The aim of the current study is to determine the nature of the relationship between indoor air quality and the socio-economic status and respiratory symptoms of mothers and children in Tirupur, Coimbatore district in Tamil Nadu State, India (see Appendix E, Figure 1 & Appendix I, Figure 1c).

1.6.1 Specific Objectives

1) To determine the extent to which differences in exposure to indoor air quality, as indicated by concentrations of fine particulate matter (less than 2.5 micrometers in diameter) ($PM_{2.5}$), and carbon monoxide (CO), can influence the prevalence of respiratory symptoms among mothers and children in Tamil Nadu.

(2) To determine the extent to which socio-economical factors, (low SES and/or poverty) such as family income, employment and educational levels, influence the use of biomass fuel (wood, agricultural waste and small shrubs) and related concentrations of $PM_{2.5}$ and CO.

(3) To evaluate the literature to determine the extent to which socio-economic factors and house characteristics may affect the relationship between indoor air

pollutants and respiratory symptoms among mothers and children in the domestic environment in Tamil Nadu.

(4) To propose recommendations covering types of fuel selected, improving household characteristics and social variables (family income, level of education and type of employment) in order to create a safe and healthy indoor environment in Tamil Nadu.

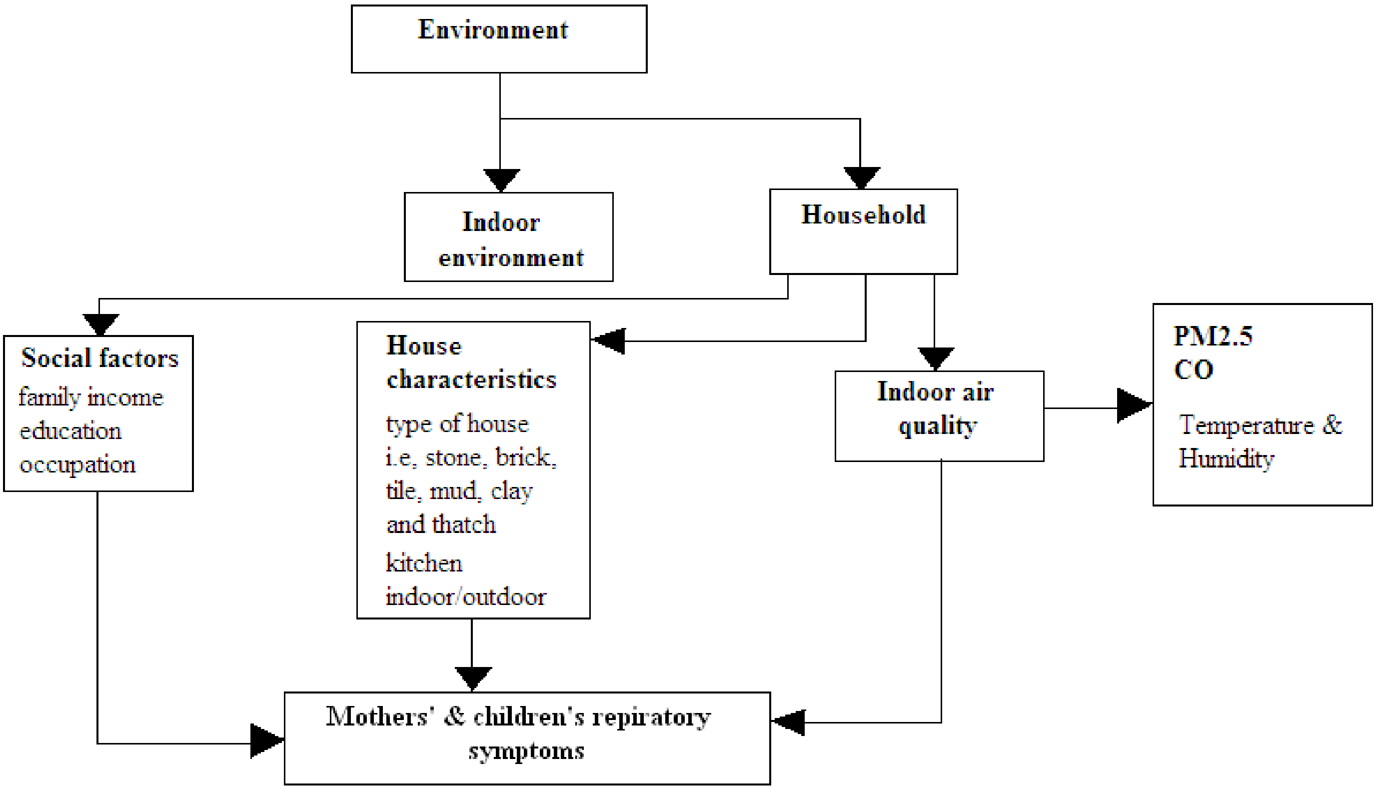
1.7 The significance of the study

The current study’s outcomes will provide valuable information for intervention studies aimed at improving indoor air quality in households in Tamil Nadu State and other states in India. It will help to create a healthier indoor air environment for mothers and children by raising households’ SES and/or reducing poverty levels by improving their family income, educational levels, employment, and health.

1.8 Structure of the thesis

In summary, this thesis comprises an investigation of health effects caused by domestic indoor air quality among poor households of mothers and children from Tamil Nadu State, in India. (see below the conceptual diagram of the current study, p.10). Chapter 2 gives a country profile of India and a state profile of Tamil Nadu State, India**.** Chapter 3 reviews other studies, identifies the limitations and disadvantages that result from limited resources, and/or interest or support. These chapters also review the current relevant literature related to the main features of the households’ indoor environment and health effects on mothers, children and their economic well-being. It also reveals poverty’s (SES) influence on household health and concludes with the potential domestic environmental risk factors associated with the use of biomass fuel for cooking, space-heating, lighting homes, and boiling water. Other contributing factors include characteristics (kitchens and houses) of the household (main variable) and its activities, especially in the kitchen. Chapter 4 deals with methodology and describes data collection and methods used for the questionnaire survey in Tamil Nadu, in India. Chapter 5 shows the results of the current study through statistical analyses. Chapters 6 & 7 discuss and conclude with recommendations and suggestions on how to improve the household environment, and alleviate poverty. Raising the incomes of the poor may not be enough to reduce poverty but might mean the economic empowerment of households' SES and an improvement in the health conditions of mothers and children in the long run (Wagstaff, 2000; Howells et al., 2005: Rahman, 2006). (See Appendix E, Figure 1). Finally**,** the current study hypothesises that SES will act as an effect-modifier of the association between indoor air pollution and mothers' and children's respiratory symptoms in Tamil Nadu (Charafeddine and Boden, 2008).

Conceptual framework of the current study



Indoor air quality, respiratory symptoms among mothers, children, and association with housing, environmental and social-economic factors in Tamil Nadu in South India.

CHAPTER TWO

INDIA AND TAMIL NADU STATE

A LITERATURE REVIEW

2.1 Country profile–India

2.1.2 Demographic factors

The current study area was located in Tamil Nadu, which is one of the states of India. According to the UN, there are 1.24 billion people in India (Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (PDDESAUNS, 2005). The literacy rate for the total population is 59.5% (for males, 70%, and for females, 48.3%). The infant mortality rate is 54.63 deaths per 1,000 live births and the fertility rate is 2.73 children per woman. The average life expectancy is 64.71 years for the total population (for males, 63.9 and for females, 65.57 years). In India, 72% of the people live in villages and the rest live in 200 towns and cities.

2.1.3 Socio-economic status

At the start of the new millennium, 260 million people lived below the poverty line in India and it is home to 22% of the world's poor (1-to-5% hungry, consumption poverty is 26%, income poverty ($1 a day) 34%, malnourished, 47% and calorie deficient 53%) (Census of India, 2001a; World Bank (WB), 2004: Veron et al., 2006; Saxena and Ravi, 2006; UN-Female Poverty Alleviation (UNFPA), 2007). There are a number of social problems in India. The most significant of which are poverty, illiteracy, unemployment and the population explosion, secularism and communalism, violence against women, and corruption at all levels. There are multiple cultural barriers and social evils (the social evils can be viewed at a macro-level that includes national and regional issues, households and individuals (Gupta and Kumar, 2007)) at household and individual level, these can influence health and relate to class, caste, ethnicity, religion and gender inequality. One of the important social evils that perpetuate ill-health in a society is gender bias or female under-empowerment (Gupta and Kumar, 2007).

When analyzing a household’s SES and/or poverty levels, income, education and occupation are examined, particularly on the Indian sub-continent, and social factors such as people’s ethnicity and caste can play a big part in their economic and social lives. In spite of increasing economic progress in recent years, India’s population still faces challenges dealing with corruption (at all levels), poverty, malnutrition, unemployment, disease and disability (Allred et al., 2003). At the beginning of the 21st century in India, hunger is 1-to-5% and Indian’s poverty levels are now more likely to be around 26% (State profile of Tamil Nadu, 2007; Saxena and Ravi, 2006; WHO, 2007d). India’s poverty levels decreased from 50% in early 1970 to about 30% in the late 1990s in terms of the head count index (Kajisa and Palanichamy, 2006). However, over the period 1987-88 to 1999-2000, in both urban and rural areas (75% of the poor live in rural areas), poverty declined, but this decline has been seen mainly in urban areas (Dewaram and Negdeve, 2002). The Indian Union (Central/Federal) and State Governments have enhanced allocations for the provision of education, health, sanitation and other facilities, which can help the well-being of the poor.(Tamil Nadu Employment and Poverty Reduction Project (TNEPRP), 2003; Kajisa and Palanichamy, 2006). There are about 314 billion rupees (A$9 million), available annually for poverty alleviation in India and the percentage of people below the poverty line, reduced from 56.4% in 1993-94, to 26.1% in 1999-2000 (Indoor air (IA), 2005).

India’s booming economy has grown by an average of about 8.5% a year and 90% of the primary energy use is biomass fuel. Poor households have little opportunity or resources to use less-polluting fuel, therefore, mothers and daughters need to spend a disproportionate amount (50%) of time collecting fuel from a range of sources. This requires no direct financial cost, but it is an opportunity cost (“an opportunity cost is the idea that the use of limited resources, such as money and time, loses opportunities for alternatives” (Kanagawa and Nakata, 2004, p.11)) and the mothers are then less likely to be able to earn income to provide less-polluting fuel. Only about 18% of Indian households are reported to be using LPG or electricity (Mahapatra and Mitchell, 1999; Ram, Hazra and Chakraborty, 2001; Rao and Reddy, 2005).

The study of Rao and Reddy (2005) showed that rural households (80%) continue to depend on animal dung fuel, agricultural residues and wood. According to a Pakistan households' energy strategy study (HHESS), 54% households use wood, 18% use animal dung, 14% agricultural waste (crops, twigs and leaves), 7% use natural waste, 3% use LPG and kerosene, 4% use electricity (Padma, 2009). A recent census in India showed that about 47% houses have been classified as permanent houses, or pucca. About 20% are semi-permanent or semi-pucca and about 33% are temporary dwellings or kachha (Klaauw and Wang, 2007). Permanent house construction materials used for walls are galvanised iron, metal, asbestos sheets, burnt bricks, stone or concrete and with roof materials such as asbestos sheets or tiles. Semi-permanent house walls are made of stone, asbestos sheets, or mud and unburnt bricks, with roofs of thatch, plastic, or polythene. Temporary house walls are made of thatch, bamboo, polythene, wood or plastic and roofs of grass, thatch or tin (Klaauw and Wang, 2007).

2.1.4 Air pollution

Several studies have found that India has one of the most degraded environments in the world (Mathur, 2001; Dewaram and Nagdeve, 2002). According to a World Bank study, India's largest cities such as Kolkata, Delhi, Mumbai and Chennai, are the world's 10 most polluted (Chennai, the capital of Tamil Nadu, is the 3rd most polluted city in India). Delhi is the second most polluted city in the world (Hum, 2001). The pollution concentrations exceeded WHO's and the USEPA standard/guideline for PM_{10} ($65\mu g/m^3$) outdoor levels (Ravindra et al., 2006). In India, 4-6% of the national burden of disease is due to the use of solid fuel. During the last decade, in Indian big cities, air pollutants grew at an alarming rate. Some studies have found that there is an association between outdoor PM and respiratory symptoms and diseases (Osunsanya et al., 2001; Oberdoster, 2001), and, in particular, residual suspended particulate matter (RSPM). The concentration of RSPM in the indoor air was higher than the outdoor air, and the percentage of $PM_{2.5}$

to PM_{10} in the indoor air, where there was no cooking with biomass fuel, ranged from 48% to 71% (WHO, 2002). A study conducted in Delhi, showed that 67% of air pollution comes from vehicles, 13% from thermal power plants, 12% from industrial units and 8% from domestic combustion from biomass fuel. The Environmental and Pollution (E and P), (2007) study revealed it has the highest ambient level of PM_{10} over 400µg/m^3 of air pollution in selected large Asian cities.

The Air Act of 1981 is one of the important environmental laws of India. The Central Pollution Control Board of India (CPCBI) gives advice to the Union Government on matters relating to pollution, coordinates the activities of the State Boards and lays down standards/guidelines (National Ambient Air Quality Standards (NAAQS), 2005; Department of Environment and Forest (DEF), 2007; CPCBI, 2007a). There are, however, no set standards/guidelines for indoor air for Indian conditions, compared with the known standards/guidelines of other countries such as the USA, UK, and Australia or European Nations. Nevertheless, outdoor concentrations' standards/guidelines are available from the CPCBI (IA, 2005). The Board is also responsible for giving feedback to the Health Minister on issues that will have been referred to it by the Minister or other government body (Health Department) and/or agencies including non-governmental and private organizations. It is the responsibility of the Board to raise the level of awareness, as well as to stimulate public and private awareness or interest in issues related to the prevention and control of indoor and outdoor air pollution. The Air Act of 1981 also forms the basis for prevention and control of pollution, which increases not only private costs, but also the social cost (E and P, 2007). A World Bank study showed urban air pollution costs India US$1.3 billion a year (Dewaram and Negdeve, 2002).

2.1.5 Health profile

India's detrimental environmental factors account for 23% of the world burden of disease and public health risk and it has a high prevalence of disease vectors. The annual burden of disease attributable to PM in fuel is the most important air pollutant and has caused illness and premature deaths in the mega cities of Kolkata, Delhi, Mumbai and Chennai, in India. During the early 1990s in India, there were 496,059 deaths, including young children, a larger proportion of the incidence of illness was 448,351,369 and disability adjusted life years (DALYs) were 15,954,430. The total burden of disease as result of indoor and outdoor pollution in India is 5.6% or 613,397 people (Von Schirnding et al., 2000). Bruce, (2003) and Smith, (2006) identified a wide range of health impacts associated with household energy use, water supply, sanitation, poor housing and/or shelter, unsafe food, and modern hazards such as water and air pollution, unsafe disposal of waste and chemicals and inadequate health care services, even at primary health care level (Allred et al., 2003; Padhi., Ghosh and Padhy, 2009).

2.2 State profile-Tamil Nadu India

2.2.1 Geography

Tamil Nadu, where the current study's data collection took place, is located at the southern tip of India. It is the country's sixth most populous state (WBGs, 2004b; Sharp, Peters and Howard, 2004) with an area of 130,058 km². Puducherry, Kerala, Karnataka and Andhra Pradesh, all border Tamil Nadu. The climate and rainfall of Tamil Nadu is tropical, and northeast monsoons occur from December to March, and southwest monsoons June to October. The State capital city of Tamil Nadu is Chennai, formerly Madras, the fourth largest city of India (Tamil Nadu Home Page: Tamil Nadu Geography, 2009).

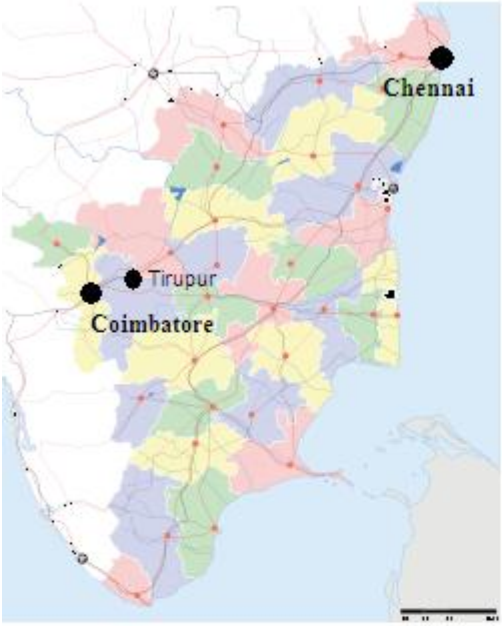
2.2.2 Demography

The total Tamil Nadu population, as per the 2001 Census, is about 62.5 (62,405,679) million people with a density of 478/km². Of this 11,858 (19%) are scheduled castes (SCs)/dalit (Census of India, 2001b). The major ethnic group is Tamil, predominantly Hindu, and makes up 6% of India's total population. It is the second most industrialised State and is one of the few countries or states in the world where both males and females have nearly the same life expectancy at birth. The overall sex ratio of Tamil Nadu is 999 females per 1000 males, which is higher than the Indian average (Velkoff and Adlakha, 1998; Census of India, 2001a). Approximately 47% of Tamil Nadu's population lives in urban areas, one of the highest percentages in India (Tamil Nadu: Profile of the Tamil Nadu, 2009). However, Tamil Nadu's population grew by 11.19% between 1991 and 2001, with the second-lowest growth in population after Kerala State (the most developed State in India) for the last decade and with a relatively low (7.7%) death rate per 1000 (Hum, 2001; Veron, 2001; Kerala, 2006; Tamil Nadu profile, 2009). Tamil Nadu has the largest urban agglomeration nationwide. The Tamil Nadu life expectancy at birth is 65.2 years for males and 67.6 for females (CIA-The World Fact Book, 2007). Hence, Tamil Nadu also has its share of India's problems such as poverty, gender (women) and caste discrimination, corruption and illiteracy (United Nations (UN), 2001a; WBG, 2004b).

About 16 million are under 15-years-old, 8% of the population is under four-years-of- age or 5,098,462 children who are aged between 0-4 and this is the most exposed group, other than their mothers, to indoor air pollutants. It has different levels of socio-economic status as well as ethnic, cultural and social differences (Census of India, 2001b). The selected area for data collection was the city of Tirupur (see Map 1 below), situated 50 kilometres east of Coimbatore, in Tamil Nadu. It is located at about 495km southwest of Chennai, the capital of Tamil Nadu. Its population (as of the 2001 India census) was 346,551. Males constituted 52% of the population and females 48%. Tamil Nadu's average fertility rate is 20.3/1000, which is less than that of the USA. Tirupur's average fertility rate (TFR) is 1.2 children per family (Census of India, 2001a; Gupta et al., 2006).

The city of Tirupur is popularly know as the "Knitwear capital" of India, which is known for its hosiery exports, provides employment for about 600,000 people (most of them are women from other cities and Indian States) and is the seventh largest city in Tamil Nadu (Tamil Nadu Home page: Tamil Nadu Geography, 2009). Tirupur is one of the fastest-developing cities in Tamil Nadu and the most polluted city, due to clothes manufacturing such as knitted garments, casual wear, sportswear and cloth-dyeing industries. The local population is predominantly a community of successful business persons and exporters. Tirupur accounts for more than 90% of India’s cotton knitwear exports and earns an annual $900 (US) million-plus in foreign exchange for India (Tamil Nadu Home page: Tamil Nadu Geography, 2009). Most mothers are employed as regular workers or in small-scale industries such are textile and cottage industries. The climate of Tirupur is generally warm, with the maximum temperature 41°C, and minimum 12°C. It becomes cool (between 16°C to 28°C) from December to February.

Map 1: Location of Tirupur in Tamil Nadu State in South India



(Tamil Nadu Home page: Tamil Nadu Geography, 2009)

2.2.3 Education

Ayres and Simon (2003) reveal that education can play a big part in poverty alleviation of poor households, particularly girls and young mothers. Attainment is strongly correlated with gender and caste, and educational exclusion is related to a range of economic, spatial, institutional, social and cultural structures and processes. Tamil Nadu’s average literacy rate of 73.47% is higher than the national average of 59% and the female literacy rate increased from 51.33% in 1991, to 64.55% in 2001, while the male literacy rate increased from 73.75 to 82.33% for the same time (State profile of Tamil Nadu, 2007). It has the highest number of vocational training institutions with 350 engineering and 1,150 arts colleges, and 2,550 schools. However, rural Tamil Nadu indicates a complex relationship between education and poverty (Ayres and Simon, 2003).

2.2.4 Poverty, social and environmental impacts on poor households

Poor people are often the most vulnerable (upper-poor and non-poor are close to or above the national poverty line). The extreme, core-poor are the poorest 50% or thereabouts, of those in poverty (Shaw, 2004). The World Bank describes vulnerability as the "resulting possibility of a decline in well-being" (World Bank, 2007, p.139). In Tamil Nadu, about 20% are living below the poverty line (World Bank, 2004a). Its population still lives in poverty and this is more acute in rural areas of the country. It is one of the better-off States because of its higher per capita income, human and social development, and steady economic growth. However, the poverty level in Tamil Nadu remains pervasive and it has the highest levels of inequality in India. A large section of the population has not benefited, as they belong to groups such as scheduled castes/dalit and tribes, minorities and women (World Bank, 2004).

People, or families, who fall into this category, have neither the access nor the means to manage their basic energy needs (Allred, et al., 2003; Pachauri et al., 2005). The poor and hungry are also destroying their immediate environment in their struggle for survival (Nayak, 2004). As revealed by the UNDP, (2004) 'poverty is one of the greatest threats to the environment". Poverty affects more females than males because the poverty levels of women and mothers are due to limited access to education, training, power, productive resources, cultural and social problems. It is the condition of the vast majority of the women mainly in developing countries who have low incomes and work long hours. (UNDP, 2004).

As revealed by a UNDP's study, it is assumed that women, who contribute 53% of a household's income, also spend an average of 8 hours a day on income-generating activities (UNDP, 2004). While poverty affects households, mothers have to bear burdens such as the pressure of unfavourable living and working conditions and have to manage household consumption and their children’s health. Households face increasing problems because of extreme poverty, such as a lack of access to basic needs such as education, health care, clean water, sanitation, nutrition and clean fuel for domestic use (LPG or electricity) (Gupta and Kumar, 2007). Better health makes it more likely that mothers can take advantage of economic opportunities (WHO, 1998; Working Women’s Forum (WWF), 2000).

The fourth specific objective of the current study will also look at the interrelationship between socio-economic status, IAQ, poverty levels, (poverty restricts the opportunity to switch to cleaner fuel and fuel types are an important variable in predicting health outcomes (Brauer and Saksena, 2002)), and economic development (see Appendix H, Figures 1a & b). As revealed by the UN health agency, if households were able to use cleaner fuel for cooking, it would lead to 473 million fewer mothers and children being exposed to harmful indoor air and possibly reduce respiratory disease deaths by 282,000 per year (UN, 2006). Household energy is inter-related with poverty and energy (see Appendix J, Figure 1) (Pachauri et al., 2004; Padhi, Ghosh and Padhy, 2009), “energy is a fundamental requirement for development and one of the most influential components of poverty reduction in developing countries” (Kanagawa and Nakata, 2004, p.15). However, there are complex and numerous links between energy, poverty and poor health (see Appendix I, Figure 1c).

2.3 Economic and socio-economic situations

Tamil Nadu is one of the more prosperous States in India in terms of per capita income, economic growth, and human and social development. The proportion of those living below the poverty line fell from over 30% in 1993-1994 to 19.6% or 12 million people in the State still living in poverty in 1999-2000 (WRI, 2000; World Bank, 2004). In 2005, the World Bank gave US$120 million credit to support the State Government of Tamil Nadu with the implementation of a comprehensive empowerment and poverty reduction program where 20% of the population lives in poverty (World Bank, 2005a). However, in spite of this, poverty remains pervasive and Tamil Nadu retains the highest level of inequality in the country, especially for women and minority groups, such as the scheduled castes/dalit. Those belonging to a lower caste, encounter a barrier to better education, better employment and certain jobs exclude people who belong to very low castes (WHO, 2001; UN, 2001a; Census of India, 2001b; WBG, 2004 a & b; World Bank, 2005). The State gross domestic product (GDP) was estimated at $56 billion on current prices, in 2004, possessing the fifth-largest economy (2004-2005) among other States in India (Mohanty and Shekhar, 2004). The programs for poverty reduction, such as infrastructure constraints and micro-enterprise development, are unlikely to facilitate the end of poverty (Amin et al., 2001; Choguill, 2001; Shaw, 2004). Hence, the government's and non-governmental organisation's (NGO's) policies are not working to meet the basic needs, such as sustainable energy for the poor sections of the society, especially the women, lowest caste communities and poor households. This is because of high levels of corruption among community representatives, local elected officials and local government officers (Veron, et al., 2006).

In 2001, total owner-occupied households in Tamil Nadu were 14,173.626, or 23% (Ravichandran, 2004). In India, including Tamil Nadu, the main environmental health problems affecting mothers and children, are illiteracy and malnutrition, and indoor and outdoor air pollution, especially domestic (UNESCO Education, 2002; Bruce, 2003). The Government of Tamil Nadu has proposed implementing a Health Systems Development Project (HSDP) with World Bank assistance the main objective of which is to improve the health outcomes of the people, with special reference to the poor and disadvantaged minorities such as mothers, children and lower castes, especially in remote and inaccessible areas. Eighty per cent of the poor in Tamil Nadu live in rural areas. Developed countries also have social and health inequalities/disparities that are produced by both environmental and psychosocial stress (In Germany, the child poverty rate in 2005 was 1.5 million (UNICEF, 2005). These problems are very common among the USA's Native and Afro-Americans, Hispanics, immigrants and other marginalized groups. As shown by the US Dept of Health and Human Services (US HHS), (2006), one of their policies was the elimination of health and income disparities because of social groups such as racial/ethnic minorities and the (economic) low-income population

(Payne-Sturges and Gee, 2006; Ou, Chun-Quan, et al., 2008). Tamil Nadu has a well-laid-out health infrastructure, both in urban, as well as in rural areas. Providing access to energy services in rural areas is a daunting challenge that is not receiving adequate attention or resources, as the result of corruption at all levels (Bruce, 2003; Veron, et al., 2006).

2.3.1 A health profile of Tamil Nadu

The health infrastructure in the public sector in Tamil Nadu has 38 medical colleges, 11 medical colleges with hospitals, 25 districts headquarter hospitals, 245 sub-district hospitals, 1413 primary health centres, and 8,682 health sub-centres (HSCs). In addition to these facilities, it has a number of maternity homes, dispensaries and health posts run by the 102 municipalities and 6 municipal corporations (Department of Health and Family Welfare (DHFP), 2008). In 1992-3, almost 50% of Tamil Nadu children were undernourished. The infant mortality rate for boys was lower than for girls (Velkoff and Adlakha, 1998), although, the study of Griffths et al. (2002) did not find any significant gender differences in weight for age z-scores, due to nutritional status. The nutritional status of Indian children in Tamil Nadu has improved since the mid-1970s (Viseanathan and Babu, 2000; Gupta et al., 2006). However, according to Velkoff and Adlakha (1998), girls and mothers die from poor health. Females have 46% prevalence of depression and anxiety because they receive discriminatory treatment as both children and adults. Despite the improvement in health services since the early ’90s, the State’s population continues to suffer from inadequate health services. Mothers and female children and are most affected. The health pattern of this State is typical of the general trend in other States in India (HFWD, 2007a).

The prevalence of ‘diagnosed’ asthma in Tamil Nadu for children 0-5 years is 5% and for 6-12-years, the prevalence of breathing difficulties, including asthma, is 18% (Chakravarthy et al., 2002). In addition, 22% of urban and 9 percent of rural children (6-12-years-old) had breathing difficulties “at any time” in the past (HFWD, 2007b). Infants less than one-year-old have a mortality rate of 30 per 1,000 live births and among children aged 1-4 years, the mortality rate is 12 per

1,000 (Ram, Hazra and Chakraborty, 2007). Public sector health services are almost fully financed by the government but the 5,000 National Hospitals, with little more than basic facilities, have incomplete patient records and indicate poor levels of care, especially at the larger hospitals. The number of children who suffer from ARI in Tamil Nadu is 22%, and there is relatively little treatment available in the health care sector and mothers provide 70-80% of health care to their children. In terms of the general disease burden and maternal health (the maternal mortality ratio is <1 per 1000 (HFWD, 2007b), the infant mortality rate per 1000 is 18.5 (CIA-The World Fact Book, 2007). The child (in rural areas), under 5-year-old mortality rate is about 100-per-1000 live-born children (Klaaw and Wang, 2007). Tamil Nadu's general death rate has a better record than other Indian States, except Kerala which has the lowest death rate in developing countries (Amarasiri de Silva et al., 2001; Conceico et al., 2001; Navaneethan and Dharmalingam, 2002; Kerala, 2006; Ram, Hazra and Chakraborty, 2007).

Despite the impressive health gains during the 1990s in Tamil Nadu, the State continues to be burdened with particular preventable diseases related to poverty, and socio-economic inequality associated with scheduled caste and gender discrimination. The disease pattern in the State is typical of the general trend in other States in India. Tamil Nadu has made considerable economic progress in recent years, except that it has to deal with poverty, unemployment, malnutrition, disease and disability (Allred et al., 2003). Diseases such as tuberculosis and respiratory infections continue to feature as major causes of mortality. The population also suffers from cardiovascular disease (cardiovascular disease contributes to 27% of these deaths in India with a crude mortality rate of 227/100, 000) and in Tamil Nadu State, the crude mortality rate is 360-430/100,000, and it is one of the highest among other Indian States (Gupta et al., 2006)) with cancer. ARI of the lower and upper respiratory tract disease continues to feature among the top hospital admissions and hospital mortality, (WHO, 1997; Mishra, 2003; Ezzati, 2004).

2.3.2 Household energy and health

Energy is an important factor; particularly biomass fuel for basic needs such as cooking, boiling water and space-heating. For poor households in Tamil Nadu, clean energy is also a prerequisite for good health among mothers and children due to Tamil Nadu's households still burning cow dung, agricultural wastes, wood and other traditional fuel inside their homes. They mainly rely on biomass fuel, as they cannot switch to cleaner fuel because of a lack of affordability (Dutt et al., 2007). Programs such as the household energy program should not only reduce child mortality and improve mothers' health, but should also help households lift out of, or from, poverty (Basch, 1999; WHO, 2006b).

Biomass resources also include municipal solid and animal wastes, food processing, aquatic plants and algae mostly used by urban poor households. These are considered the major contributors to ill-health, not only in poor households but also elsewhere in other Indian States and other developing countries (WRI, 1998; Parikh et al., 2000; Demirbas, 2001). Many studies also proved that the direct effects of IAP are caused by poor quality, particularly solid mass fuel, such as wood or agricultural wastes that can cause acute lower respiratory infection (ALRI), chronic obstructive lung disease (COLD), lung cancer (coal only), asthma and low birth-weight. Mishra et al. (2004) found that babies born to mothers who used wood for fuel were 63 grams lighter and with a higher incidence of ALRI, than those using kerosene instead of wood. Ranasinghe and Mahanama, (2004); Ekici et al. (2005) claim that mothers also had heart disease, early, obstructive airway diseases and cataracts. Cataracts or blindness because of cooking with biomass is caused by air being blown into the fire from time-to-time when the fire is smouldering or moist (Saiyed, Patel and Gokani, 2001). The use of moist fuel and smouldering fires can cause exposure to smoke and have some direct consequences such as burns, and risks associated with collecting fuel. In the rural areas of Tamil Nadu, mothers and girls spend as much as an average 50 hours every month in firewood collection and it can take 1.6 more time in food preparation than traditional fuel (UNDP/ESMAP, 2004; USEPA, 2004; Howells et al., 2005; WHO, 2006b), (see Appendix L, Photo 1c). Mathur, (2001) and Bruce, (2003) also found links with environment and gender and the close inter-relationship between energy use, health and poverty. These can form an important prerequisite for all subsequent economic development or poverty alleviation of households in Tamil Nadu and other States in India (Balakrishnan et al., 2004; Veron et al., 2006).

2.3.3 An overview of air pollution prevention and control

The responsibility for air pollution prevention and control in the State of Tamil Nadu rests with the Department of Environment and Forests (DEFs). The Tamil Nadu Pollution Control Board (TNPCB), 2007) established in 1982, and the CPCB of India, both enforce environmental laws, by monitoring air pollution levels and taking appropriate legal action against defaulters, mainly privately-owned and operated chemical and textile industries (DEF, 2007; CPCB, 2007b). The NAAQS 24-hour exposure for suspended PM (SPM) is 500µg/m^3 for industrial areas. A study of air samples from industrial pockets in Tamil Nadu for PM$_{2.5}$ concentrations is 200µg/m^3 and in sensitive areas, such as hospitals and schools, 70µg/m^3. For respirable PM, it is 120µg/m^3 for industrial areas, residential, rural areas are 60µg/m^3 and sensitive areas are 50µg/m^3. Exposure standards for CO for 8 hours is 5.0mg/m^3 for industrial areas as for residential, rural and other areas 4.0mg/m^3 and sensitive areas is 2.0mg/m^3 (Murthy and Swaminathan, 2003; Sri Raman, 2005; Sharma and Maloo, 2005). The WHO standard for CO for a 1-hour exposure (in industrial areas is 10.0mg/m^3), for residential, rural and other areas it is 4.0mg/m^3, and in sensitive areas, 2.0mg/m^3. The PM$_{2.5}$ concentrations, measured by gravimetric samples ranged from 13 to 2006 µg/m^3 (0.013mg/m^3 to 2.6mg/m^3) in rural households and 3 to 110µg/m^3 (0.003µg/m^3 to 0.011mg/m^3) in urban households in India (WHO, 2000e; Kurmi et al., 2008).

The CPCB of India spells out five environmental laws for the control of pollution, including air pollution control of the entire country at Union and State level. The State Government has declared the entire State of Tamil Nadu as an air pollution control area (E and P, 2007). Other relevant laws include the Water Act, 1974; Cess Acts, 1977 & 1985; Public Liability Insurance Act, 1981; National Environmental Tribunal Acts, 1995; National Environmental Authority Act, 1997, (CPCBI, 2007a). These Acts control offensive gases, atmospheric air pollution by smoke, fumes from various sources, such as motor vehicles (71.28%) and industry (19.70%) (The Hindu, 2007). To control noxious gases and specified processes, the State Health Department drafts regulations and sets indoor and outdoor emission standards and guidelines for tolerable or acceptable levels of all types of pollution (NAAQS, 2005; Indian Meteorological Dept (IMD), 2007 & 2008). As shown by the study of Pulikesi et al., (2005), Chennai's total suspended particulate matter (TSPM) and respirable suspended particulate matter (RSPM) values exceeded the NAAQS. However, in Chennai from 1993-2003, air pollutants declined from 10% to 5% and in some metropolitan cities, such as Bangalore from 1997 to 2004, air pollutants also decreased (Nagendra, Venugopal and Jones, 2004; Gupta and Kumar, 2005). Similar trends were also shown in Tamil Nadu's urban areas, but there were slightly lower levels in some coastal rural and urban areas (Murthy and Swaminathan, 2001-2003; NAAQS, 2005).

Peters et al. (1997) examined fine and ultrafine particles that only affected mothers and children with a history of asthma. Other studies such as Jones, (1999a), Gauvin et al. (2002) and Ward et al. (2002) looked at fine particulate matter ($PM_{2.5}$), personal exposure of mothers, children, and domestic air quality and effects of daily variations in outdoor particulate matter. Some epidemiological studies have found that there is an association between outdoor particulate matter and respiratory symptoms and diseases (Osunsanya et al., 2000; Oberdoster, 2001). According to a study, the size distribution of ambient particles helped to elucidate the properties of ambient aerosols responsible for bad health effects (Peters et al., 1997; SCR, 1998)). In Tamil Nadu, Parikh et al. (2000) examined the links between pollution and the types of kitchen, fuel used and health effect of the households. Their results show that the values of respirable particles (PM_{10}) ranged from 0.5-2mg/$m^{3,}$ during a two-hour cooking period, using biomass fuel. Evaluation of the literature reviews determined the extent to which socio-economic factors and house characteristics also modify the relationship between indoor air pollutants and respiratory symptoms among mothers and children (see Appendix E, Figure 1).

CHAPTER THREE

A LITERATURE REVIEW

AIR POLLUTANTS AND HEALTH EFFECTS

3.1 Introduction

The improvement and development of science and technology has led to environmental problems in developed and developing countries. Air pollution, both indoors and outdoors, is a major problem because it has been related to adverse health effects (see Appendix F, Figure 1). Air pollution is largely and increasingly a consequence of the combustion of fossil fuels for transport, power generation, household and human indoor and outdoor activities (Garbino, 2005). Air quality is distributed by physical, chemical, and biological factors, and their relationship to human health (Jones, 1999b). Pure air is comprised of concentrations of 21% oxygen, 78% nitrogen, 0.07% carbon dioxide, 0.93% argon and a number of rare gases, of which argon is the most plentiful (WHO, 1999). The atmosphere contains poisonous gases which, at higher than usual concentrations, can cause adverse health effects to humans and animals, and damage plants. These include lead (Pb), ozone (O_3), sulphur dioxide (SO_2), nitrogen oxides (NO_x)), carbon monoxide (CO), and particulate matter (PM). These are commonly known as the six common air pollutants, all potentially toxic (WHO, 1999; United Nations EPA (UNEPA), 2007). For many centuries, airborne pollutants, and their impact on human health, have been a matter of increasing public concern. Over the last twenty years, a considerable number of studies have reported adverse health effects associated with indoor and outdoor air pollution, ranging from respiratory symptoms and illness, impaired lung function, hospitalization for respiratory and cardiac diseases, to increases in mortality (American Thoracic Society 1985).

Air pollution is not restricted to one district or locality; it can be international. The haze episodes that occurred in Malaysia in 1991, 1994 and in 1997, have been attributed to suspended smoke particulate matter from biomass burning in Southern Indonesia (Radzi bin Abas, Oros and Simoneit, 2004). In addition, there were other human factors, such as the population of the world, which surged from 2.4 billion in

1950 to 6.1 billion in 2000, due to decreasing death rates in developed countries and high birth rates in developing countries (Weeks, 2002; The Status of Women, 2004).

3.2 Outdoor air pollution, sources and health effects

Outdoor air pollution (see Appendix F, Figure 1) is one environmental effect which can play a major part in environmental degradation. According to Senarath, (2003) and Rebizer et al. (2004), environmental impacts include pollution from emissions into the environment and through the consumption of resources. Other interventions include land use, extracting resources, producing materials, manufacturing products and during consumption; how we reuse, recycle, dispose of waste, human activities and naturally. All these factors contribute to a wider range of impacts, such as climate change, tropospheric ozone (O_3), (the ozone standard has dropped from 120 $\mu g/m^3$ down to 100 $\mu g/m^3$ (WHO, 2006a), creation, stratospheric ozone depletion, eutrophication, acidification, toxicological stress on human health and ecosystems, the depletion of resources, water use, land use and noise, among others (Pennington et al., 2004; Donohoe and Gamer, 2008). Factors affecting the concentrations of outdoor air pollutants are meteorological and demographic. In developed countries, the combustion of fossil fuels in transportation, manufacturing and power generation, like motor vehicle and industrial activities, also contribute to outdoor air pollution (WHO.1999; Villeneuve et al., 2001).

In both developed and developing countries, in the urban environment, there are higher concentrations of sulphates, nitrates, organic compounds, metals and fine particles that show greater toxicity than coarse particles. (WHO & Western Pacific Regional Office (WPRO), 2004). Now both regions are increasingly facing a growing number of very similar outdoor air problems and health effects in their countries (Jones, 1999a). Because air pollution causes undesirable changes in the physical, chemical and/or biological areas, it can adversely affect plants, animals, human health and inanimate objects (Senarath, 2003). When ozone concentrations reach high levels, it can cause respiratory and asthma attacks.

3.3 The management of outdoor air pollution

Not only national and international organisations, but also scientists and policymakers, have shown growing interest in the health effects of chronic air pollution exposure (Jerrett et al., 2005). Poor outdoor air problems cost millions of dollars in both developed and developing countries. Poor air quality in Australia may be costing the nation as much as US$12 billion a year through human ill-health and lost production. According to a World Bank study, India’s estimated environmental damage in the year 1992 was US$10 billion a year (Dewaram and Negdeve, 2002). Unfortunately, not much attention has been paid to the analysis of various issues associated with rural energy supplies, particularly clean and convenient sources of energy, especially in developing countries, caused by various factors such as the country’s poverty levels and government corruption (Wijayatunga and Attalage, 2002). Many governments and private, national and international organizations have become concerned about the adverse health effects associated with exposure to air pollutants.

As the result of the range of urban reforms to improve the sanitary conditions of urban life, the Health of Towns Act (1853) the Alkali Act in (1863), to control new pollution by industrial emissions, and the first Public Health Act (1875) were introduced in to Britain. The 1926 Smoke Abatement Act was introduced to reduce smoke emissions (pollution) from industrial sources in urban areas (History of Air Pollution (HAP), 2005). The London Fog (smog) of 1952 led to the introduction of the Clean Air Acts of 1956 and 1968. In 1974, the Control of Air Pollution Act was introduced as a result of an increase in motor vehicles. During the 1980s and 1990s, further increased use of motor vehicles caused the British Government to pass its Environmental Act in 1995 to improve national air quality throughout the UK by 2005 (HAP, 2005). In Australia, the following Acts were introduced over the years by such bodies as the Department of Conservation and Land Management; the Bush Fires Act in 1954; Australian Environmental Protection Act 1986 as amended in 1987, Environmental Protection (ozone protection) Policy 1993 and 2000 and the National Environment Protection Council (NEPC WA) Act in 1996. In addition, the National Commission was established under the National Occupational Health and Safety Commission Act 1985. In the USA, one of the earlier Acts was when the cities of Chicago and Cincinnati enacted clean air legislation in 1881. Since the middle of the 1950s, USEPA has passed various pollution control acts such as the 1955 Clean Air Legislation, 1963, 1970, 1990 Clean Air Acts, and the Air Quality Acts of 1967, 1970, 1977 and 1990 (Clean air #1, 2007). As revealed by the American Lung Association (ALA), (2006) over the past three decades, legislation has been implemented to ensure the quality of the environment, and thereby improve public health. The Air Management Information System (AMIS), set up by the WHO, is based on voluntary reporting of information or data on air pollution from developing countries by municipalities of the WHO member States of concentrations of SO_2, NO_2, O_3, CO, SPM and lead and other potential-monitored compounds (WHO, 1999).

According to the WHO (2000a), air quality management should be developed and implemented as a matter of urgency in those cities where strategic planning is weak or non-existent. Short-term, feasible approaches to reducing existing air pollution should be implemented as soon as possible and energy conservation, inspection of motor vehicles, phasing out of leaded petrol, alternatives to open burning and refuse disposal and high-sulphur coal and oil used by industries, should be undertaken. In the long term, preventive measures in the development of management strategies should be used to improve outdoor air quality that is using new “clean” technologies. Management strategies should aim at protecting public health and not only a clean outdoor environment.

Air pollution problems, whether indoors or outdoors are very complicated, although the nature of the standard/guidelines is to provide a basic knowledge for protecting human health in general. The set standards/guidelines are considered to protect health; they are by no means a “green light’ for controlling air pollution. It is difficult to achieve no-risk situations, but at least reducing or minimising risk should be attempted (WHO, 2000e). The WHO challenges the world to improve air quality by reducing particulate matter pollution from 70 to 20 $\mu g/m^3$ (new Guidelines). It estimates that this can cut deaths by around 15% per year. This means some cities from developing countries should reduce current pollution exposure levels by more than three-fold.

3. 4 Indoor air pollution, sources and health effects

Indoor air pollution (IAP) is one of the major human health concerns and is increasingly attracting attention globally because people spend more time indoors (80%) than outdoors (it is generally recognized that Australians spend 90% of their time indoors, 7% in cars and only 3% outdoors (Commonwealth Scientific & Industrial Research Organisation (CSIRO), 1998; DEH, 2004)). Indoor air quality is a significant health, environment, and economic issue, particularly in developing countries (Rumchev, Brown and Spickett, 2007). Indoor air pollutants are a major environmental and public health hazard, especially in the world's poorest nations (WHO, 2002). One half of the world's population, and about 95% in developing countries, mainly Asia and Africa (95% of the population in Afghanistan and Chad, 87% in Ghana, 82% in India and 80% in China, use biomass fuel) continues to rely on solid fuel, including biomass fuel and coal, to meet their energy needs (Duflo et al., 2008). Indoor air quality includes physical, chemical, and biological pollutants, and their relationship to people's health (Rumchev, 2001).

The nature of IAP can be diverse, and can be found in different environmental conditions, such as inside offices, the 'sick building syndrome' (SBS), private homes (domestic), inside vehicles and aircraft passenger cabins (Hocking, 1988; Costa and Brichus, 2000; Weinhold, 2001; Kandiah, 2001; Becker, Salim and Kelmon, 2006). Indoor air pollution and its health effects is not a new phenomenon. In 1285, when coal was used as fuel, the wife of King Henry III complained about indoor coal smoke in Nottingham Castle (Brimblecombe, 1999). Recently, China designed new stoves for the conservation of wood fuel resources implementing deceptively-simple technology using charcoal, which has an advantage over kerosene or LPG and electricity, and produce short-term reductions in emissions of health-damaging indoor pollutants. They also help the long-term goal of reducing greenhouse gas emissions (Environment Australia, (EA), 2003; Edwards et al., 2004). Recent Indian studies showed that in measurements of fine particulate matter and carbon monoxide taken for a 48-hour period in indoor kitchens of 110 households, before and after installation of improved stoves, the CO mean concentration was reduced, on average, by 39% and the mean $PM_{2.5}$ concentration was reduced, on average, by 24% (Oanh, et al., 2005; Dutta et al., 2007).

One of the main contributors to indoor non-biological pollutants is outdoor sources, especially if the buildings or houses are situated in urban areas, close to an industrial area or streets with heavy traffic. An Indian study found that indoor air quality is dominated by contributions from indoor sources, rather than from outdoor sources (Monkkonen et al., 2005). Evidence has indicated that indoor air can be more seriously polluted than outdoor air. Poor indoor air can be emitted from by-products of the building, occupants' activities, emissions from biological sources and building materials and the types of fuel used for domestic activities and house pets (Jones, 1999a). Some pollutants can infiltrate from outside, either through water, ground or air. About 52% of the world's population uses biomass fuel for cooking, space-heating and boiling water in their rural homes in developing countries and the percentage varies between countries and regions. This ranges from 36% to 95% in most developing countries in Africa and South-East Asia, 74% in India, and 90% in China, and 16% in the Eastern Mediterranean Region. In most developed countries, biomass fuel represents only 3% of primary consumption. In some countries biomass energy comes mainly from wood, for indoor heating (Demirbas, 2001; Refuses, 2006; Yen, O'Hara and Akimoto, 2006; Davis, 2006).

The world produces about 146 billion metric tonnes of biomass a year, mostly wild plant growth (Demirbas, 2001). About 15% of the world's primary energy consumption is from biomass and 38% of the primary energy of developing countries is from biomass. Furthermore, biomass produces 90% of rural primary energy in developing countries, including India. It has the largest share in the supply of energy in developing countries, particularly rural parts of these countries (Demirbas, 2001; Brauer and Saksena, 2002). Indoor emissions from biomass burning produces particulate organic matter (POM), which can have significant impacts on local and regional air quality, ecosystems, visibility and global radiation budgets and climate change (Jalal and Rogers, 2002). A number of studies on indoor air quality, especially domestic air quality, have found many organic pollutants in both urban and rural households in developing countries (Gokhale and Khare, 2007). Biomass fuel, used for combustion, can produce carcinogenic polycyclic aromatic hydrocarbons, which have been found in kitchens, fireplaces, and from smoking (Rahman, Sakamoto and Fukui, 2005). Indoor smoking (passive smoking) is an important determinant of indoor air pollutants such as PM and CO exposure (Lai et al., 2004), in lounges, as well as smoke from incense sticks and candles (Schwartz, 2000; Mishra et al., 2004; Perera and Mahanama, 2004; Ranasinghe and Mahanama, 2004). Emissions from products of incomplete combustion are present in poorly-ventilated kitchens and cooking areas. Traditional stoves or three-stone fires or pits, are often not vented with flues, and stoves are normally located in areas with low roofs or ceilings, making it necessary to squat, so that mothers' and children's faces are in close proximity to smoke which can cause serious health problems. These can emit very highly-concentrated particulate matter and noxious gases indoors (Zhang et al., 1999; Demirbas, 2001; Oanh, et al., 2005; Donohoe and Gamer, 2008). If the kitchen or stove has a chimney or flue, concentrations of fine particles will be reduced by 90 per cent (Padma, 2009). This exposure is not limited to the cooks alone; mothers and children, and other family members in the vicinity are also exposed through a "passive cooking effect" (Parikh et al., 2000). However, the relative importance of any one source depends on what amount of a given pollutant is emitted and how bad to human health it could be (Rumchev, 2001).

Indoor air quality (IAQ) has been recognised as a significant health, environment, and an economic issue in many countries, particularly developing countries (Rumchev, Spickett and Brown, 2007). According to the WHO, (2002), there is a paucity of evidence for the following health effects such as lower birth weight, perinatal mortality, otitis media, tuberculosis, (about 0.5 million people die every year in India from tuberculosis, and the number has remained the same for the last five decades (Deogaonkar, 2004)). Early cataracts, asthma, cancer of the nasopharynx and larynx, lung cancer in biomass-using households, (a leading cause of death linked to biomass smoke is malaria in adults in developing countries every year (Donohoe and Gamer, 2008)), lung fibrosis, interstitial lung disease and cardiovascular disease, because of poor IAQ. In addition, it may be associated with the incidence of infectious diseases. Because of deteriorating indoor environmental conditions, there is also an increase in ill-health and premature mortality in many millions of people in developed and in developing countries (Brimblecombe, 1999; Emmanuel, 2004; Ayres, 2006).Every year, in India indoor air pollution kills 1.6

million people (over 1.5 million females die prematurely every year from inhaling indoor air pollution (Padma, 2009)), that is, one death every 20 seconds and the eighth most important risk factor to the burden of disease (WHO, 2005c). However, it ranks third in the Indian burden of disease (Padma, 2009). In India alone, 4-5 million premature deaths per year among women and children under five are as a result of households using biomass fuel for cooking and boiling water (Smith, 2000b; Koyuncu and Pinar, 2007). Mothers, being the chief cooks, spend three-to-seven hours per day with the stove, preparing food, and 59% of all deaths are attributable to indoor air pollution. Also 56% of all indoor air pollution-attributable deaths occur in children under five years of age and 2-3 million children under five die because of lower breathing tract diseases (WHO, 2005c; Padma, 2009). Globally, indoor air pollution of biomass or solid fuels is responsible for 2.7% of the burden of disease (WHO, 2005c). Biomass use will remain the main household fuel for a long time to come in many developing countries even if female members of households do not collect it freely. In sub-Saharan Africa and South Asia, more than 80% of the households use solid fuel (WHO, 2007b; CHP/PCOR, 2008). The emissions from biomass combustion are 10-20 times higher than WHO’s recommended upper limits (Donohoe and Gamer, 2008).

The quality of the air inside a home can be very poor because indoor pollutants are generally not easily dispersed, diluted or released to the outside environment (Gauvin et al., 2002). In most homes in developing countries, the concentration of indoor air pollutants is very high, because of the use of biomass fuel, poor ventilation, faulty appliances and house characteristics, which may be detrimental to human health, especially to mothers and children (WHO & WPRO, 2004; Behera, Sood and Singhi, 1998). In addition, indoor air quality of the home can vary according to the number of occupants, type, nature and level of households’ indoor activities, (using biomass fuel for cooking and smoking indoors), the air exchange rate or ventilation and indoor environmental conditions (Bouhamra et al., 2000; Spickett, 2005). Where coal is used, there would be additional contaminants such as sulphur, arsenic and fluoride present in the indoor air (USEPA, 2000; Isbell, Stolzberg and Duffy, 2005). However, the urban environment involves health hazards with an inequitable distribution of exposure and vulnerabilities (Berrueta, Edwards and Masera, 2007; Kjellstrom et al., 2007).

There is clear evidence to demonstrate a significant association between air pollution and adverse health effects. Every day, IAQ is responsible for 4,000 deaths globally (Rehfuess, 2006). A study estimates that indoor air pollution associated with household use may be causing 2.5 million deaths annually in developing countries. (Balakrishnan et al., 2004; Howells et al., 2005). The WHO has estimated that because of acute respiratory infections (ARIs) there are about 1.6 million deaths per year. The leading killer of children throughout the world, in 2004, was ARI (Bruce, 2003). The study of Costa and Brichus (2000), also suggested that indoor air pollution could be significantly associated with respiratory symptoms in mothers such as coughs, chest illness, lung disease and bronchitis. The symptoms also include reduced lung function, bronchitis, tuberculosis, low birthweight, toxins for cataracts and the aggravation of existing conditions of cardiovascular disease and ARI and asthma in mothers and children. Children were more susceptible to domestic air pollution because exposure levels were dependent on their body weight (Maroni, 1995). Therefore, their health risk may be greater from domestic air pollutants than outdoor air pollutants. It is also clear that indoor air pollutants are causing clinically-relevant diseases and creating social and economical problems, especially among the poor, especially in rural parts of developing countries. The degree of potential exposure and public concern about the health risks associated with indoor air pollutants are not going to disappear in the near future, particularly from developing countries (Jones, 1999b). The total burden of disease caused by indoor and outdoor pollution in India is 5.6%. (Von Schirnding et al., 2000).

3.5 Particulate matter (PM) sources, health effects and standards/guidelines

Particulate matter (PM) is a combination of both solid and liquid particles including nitrates, sulphates, dust, sand, metals and organic chemicals. Toxicity, size and other properties are highly variable (Crawford and Williams, 2006). PM is one of the most important air pollutants and can vary in size, physical and chemical composition, and source (WHO & WPRO, 2004)). PM is a component of aerosols, that is, a suspension of liquid and solid particles in the air (McKendy, 2000). Atmospheric particle sources are from natural bio-organic detritus such as plant wax, (natural blow-off), vegetation detritus, soils and from antheroponic emissions such as motor vehicle exhaust, soot (soot carbon is predominately a major component of $PM_{2.5}$ (Frazer, 2002)). Biomass burning (taxon specific, wildfires, heating), and anthropogenic emissions, (cooking and industry), are other sources. Coal and charcoal burning also emit particles with characteristic organic compound traces that are source-specific (Simoneit, 2002). PM chemical composition, number, and size distribution (the mass of ultrafine particles) can vary with time and location (rural people especially in developing countries receive as much as two-thirds of the global exposure to particulate matter (WHO, 2000a)), (Lonati, Ozgen and Giugliano, 2007), and also where the wind speed was the dominant factor for ultrafine (10-100nm) particle concentrations. In poorly-ventilated kitchens, indoor concentrations of small particles were 100 times more than outdoors (WHO, 2005c).

“Re-entrained” (formed by the earth’s crust and vehicular traffic) dust accounts for the bulk of the “coarse” PM_{10} fraction, but usually less than 30% of the fine fraction. “Secondary” particles make up a significant fraction of the ambient $PM_{2.5}$ in many cities. (Air Resource Management Center, 2001; Ilacqua et al., 2007). Also fine and ultrafine particles are emitted directly from a number of natural and anthropogenic sources as well as being formed in the atmosphere. Ultrafine particles (UFP) were defined as particles of 10-100nm in diameter and the accumulated mode was represented by particles having diameters between 100 and 368nm, emitted directly from a number of natural and anthropogenic sources as well as being formed in the atmosphere (Srivastava and Jain, 2007). Maintenance of good indoor air quality for homes using biomass fuel for cooking could be very challenging because it emits a large amount of ultrafine and supermicron particles (WHO, 2006a).

A vehicle’s engine is also a source of PM and can contribute to urban environmental particle concentrations (Kittelson, 1998; Molnar et al., 2002). This concentration can also be altered by changes in the specification of weather conditions such as indoor temperature, humidity, wind speed and individual characteristics (Vichit-Vadakan et al., 2001). The exposure standards/guidelines for PM_{10} set by the EPA and Australian National Environment Protection Council (ANEPC), for 24-hours is 50µg/m^3 and the Australian National Health and Medical Research Council (ANHMRC) for total suspended particles (TSP) was 90ug/m^3. Currently there are no standards for IAQ exposure in Australia although NHMRS offers other standards. Therefore, ambient air quality standards are applied when necessary. The National Environment Protection Measure (NEPM) does not have current indoor air quality standards, as the ANHMRC has, but is currently reviewing standards. In addition, no air emission standards for $PM_{2.5}$ and for ultrafine particles have been established in Australia, (Commonwealth of Australia, 2001). The USEPA standard is 150µg/m^3 and the European Union's is 40µg/m^3, the WHO's short-term (low level) exposure guideline is defined as 0-100 µg/m^3 and the 24-hour average concentration of PM_{10} is 100 µg/m^3 (WHO, 2000b). Current WHO standards for PM_{10}, 50ug/m3, and $PM_{2.5}$ 25ug/m^3, respectively, are for 24 hours mean (WHO, 2005a). The ambient air quality of NEPM for PM is 50µg/$m^3$for 1 day (NEPM, 2009). That of NAAQS for PM_{10} is 150 µg/$m^3$for 24-hours and for $PM_{2.5}$ 15.0µg/$m^3$for 1 year (US EPA, 2007). The old WHO's guideline for PM_{10} was 70µg/m^3 but the new guideline says that to prevent ill-health, those levels should be lower than 20µg/m^3 (WHO, 2006c).

As shown by studies from Asia, Africa and Latin America, $PM_{2.5}$ indoor exposure levels can reach 3000µg/m^3 (3mg/m^3), even 10,000µg/m^3(10mg/m^3), during cooking. The evidence is that airborne particulate matter (PM) can cause serious human health effects. This problem continues to be ignored by the world community, (nearly two billion people in the world are subjected to exposure of particulate matter and up to 10-20 times higher concentrations than the WHO's guideline, especially in developed countries (WHO, 2006a).

According to Dasgupta et al. (2006) and Rao and Reddy, (2005), when using biomass fuel, PM_{10} daily average indoor concentrations of 300µg/m^3 are not unusual in some households. Biomass fuel smoke is the fourth risk factor contributing to high mortality in developing countries (Bruce, 2003). High daily average indoor particles' (PM_{10}) concentrations over 300µg/m^3 were found in many poor families' households (kitchens) in developing countries (Dasgupta et al., 2006; Lee, 2003). In these countries, large populations, especially households, are exposed to high levels of combustion particles derived from indoor stoves without flues and open fires. Major sources of $PM_{2.5}$ emission in the cities of developing countries include soot and condensed vapours from combustion in vehicles (long-range transport, diesel vehicles and two-stroke motorcycles), stationary combustors, and open burning of domestic and agricultural wastes.

One study concluded that most of the indoor suspended PM is outdoor-borne, which enters through open windows, poor ventilation, or because of re-entrainment of the existing particles already inside the house (Tuomiso et al., 2005; Molnar et al., 2002). Another study found that ultra-fine particle (UFP) concentration was high in a large city compared to a medium-sized city and lowest at sites that are more rural and where cooking and candle-burning took place (Matson, 2005). The main source of indoor (domestic) $PM_{2.5}$ in developing countries is due to using biomass fuel for cooking and boiling water and indoor smoking. $PM_{2.5}$ was monitored in the indoor air of a range of homes in Tamil Nadu in India for the purposes of the current study because the effects of biomass fuel smoke typically focus on pollutants PM and CO. Around 80% of global exposure to PM occurs indoors in developing countries because of households' use of biomass fuel for cooking and other domestic uses (Behera, 1995; Kumar et al., 2008). Unfortunately, biomass fuel will remain the principal household source of energy in many developing countries, including India, for a long time to come (20 years) as long as poverty exists, thus affecting the health of its communities (WHO, 2007b).

3.5.1 Particulate matter and health effects

Air pollution is more serious and has more health effects when caused by particulate matter (PM) especially fine, ultrafine and nanometer sizes, even at lower levels (Peters et al., 1997; Brunekreef et al., 1998). $PM_{2.5}$ (<2.5µm) can penetrate deep into the lungs, where it can cause morphologic and biochemical changes (Rinne et al., 2007). A study from the USA estimated that approximately 64,000 people in the United States die prematurely from heart and lung disease every year caused by particulate air pollution, more than people who die each year in car accidents there (Shprentz, 2000). Asthma is one result and is a common disease, a chronic inflammatory disorder of the airways. Studies have found that exposure to particulate matter, especially fine and ultrafine (which contains some toxic matter, and tends to enter smaller airways, or alveoli, more easily (Churg and Brauer, 2000)) can lead to premature mortality, especially among children and elderly people with a pre-existing chronic respiratory illness and asthma (Morgan et al., 1998). The range of risk was found to be 1.2-4.4% increased mortality per 10mg/m^3 incremental increase in the level of respirable particles. Morgan et al. (1998) found that there was an association between pulse rate and PM_{10} among elderly participants. Fine and ultrafine particles (D_p>50nm- D_p>100nm) can also aggravate existing conditions of cardiovascular disease, causing breathing and respiratory problems (EPA, 1999; NPI, 1999). The concentration of nanometer-sized particles is more dangerous than micro-sized particles (Kittelson, 1998; Molar et al., 2002). The most common and obvious health problem due to IAPs, is the increase in the incidence of respiratory morbidity among mothers and children who have been using traditional biomass fuel for domestic use.

Acute respiratory infection is the main cause of mortality in children aged less than 5 years with 3-5 million deaths annually in this age group (WRI, 1998; Mathur, 2001). Ultrafine particles can increase coughing and illness during the night and aggravate existing conditions of cardiovascular disease, causing breathing and respiratory problems (EPA, 1999; Ayres, 2006 NPI, 1999 & 2009). Ultrafine particles (0.01 to 0.1 microns) contain a disproportionate amount of toxic substances, such as lead and arsenic. They can cause lung cancer because they carry carcinogenic vapour and cause further adverse health effects such as respiratory infections, bronchitis, eye, nose, and, throat irritations, and symptoms including headache, dyspnoea and vomiting (WHO, 1999). Fine particles are the most poisonous particles, with an aerodynamic diameter less than 2.5 microns, and appear to have the greatest health-damaging potential. They can be carried deep into the lungs and can cause inflammation and scarring to lung tissue and carry surface-absorbed carcinogenic compounds into the human lungs (Senarath, 2003; WHO and WPRP, 2004).

Particulate matter concentrations are increased by cooking styles such as frying (Massey et al., 2009). A strong connection was observed between suspended particulate matter and infant mortality in urban areas. (E & P, 2007). Exposure may increase the risk of a number of other important conditions, including tuberculosis (TB), adverse pregnancy outcomes such as low birth weight (households' use of high-pollution cooking fuels, such as biomass, can produce a high concentration of $PM_{2.5}$, babies will be 175g lighter in weight than from mothers using LPG, natural gas or electricity (Mishra et al., 2004)). Early cataracts, asthma, tuberculosis, ischaemic heart disease, intestinal and lung disease, nasopharyngeal and laryngeal cancers, are the result. Coal use can double the risk of cancer, particularly among mothers (Von Schirnding et al., 2000; Sanchez-Perez et al., 2001; WHO, 2006b). Indoor urban $PM_{2.5}$ causes mortality and other health effects in residential and occupational buildings (Chase et al., 2000). $PM_{2.5}$ causes an estimated loss of statistical life expectancy of 8.6 months for the average European (WHO, 2006c). According to WHO's global update 2006, reducing levels of one particulate type of pollutant (PM_{10}) could reduce mortality in polluted cities by as much as 15% every year (WHO, 2008).

3.6. Inorganic pollutants

3.6.1 Carbon monoxide (CO) sources, health effects and standards/ guidelines

Carbon monoxide (CO), a colourless, odourless, tasteless, toxic and non-reactive gas, is a primary and widely-distributed air pollutant. Natural ambient concentrations of CO can range from 0.01-0.23mg/m^3. (WHO, 1999; NPI, 2009). The main sources of CO are industrial plants, cigarette smoking (indoor), incomplete combustion of carbon-containing fuels, (vehicle exhaust), and malfunctioning household equipment. It survives in the atmosphere for about one month but it becomes carbon dioxide (CO_2) after oxidation (WHO & WPRO, 2004). According to the WHO, the global background concentrations of CO are between 0.06mg/m^3 and 0.14mg/m^3 (0.5-0.12ppm). Environmental tobacco smoke (ETS) in homes, offices, inside vehicles and indoors can raise the 8-hour average

CO concentration from 26 to 46mg/m^3 (20-40ppm) (WHO, 2000b). No standards for CO have been agreed upon for indoor air. However, the US National Ambient Air Quality Standards (US NAAQS), for outdoor air are 9ppm for 8 hours and 35ppm for 1 hour (US NAAQS, 2009). As revealed by the National Institute of Occupational Health (NIOH), CO causes a serious problem when using biomass fuel. During its household use concentrations of CO can reach 144µg/m^3 (0.144mg/m^3) when using animal dung, 156µg/m^3 (0.156mg/m^3) when using crop residues, 95 µg/m^3 (0.095mg/m^3) when using wood and in cases of using kerosene, can be around 108µg/m^3 (0.108mg/m^3). During the use of LPG, the CO levels are very low, at about 14µg/m^3 (0.014mg/m^3) CO (NPI, 2009; Mathur, 2001). CO prevents the normal supply of oxygen in the blood and can reduce the supply of oxygen to the body tissues and heart (WHO & WPRO, 2004).

According to NPI (2009), health effects related to CO exposure are poor concentration, loss of memory, vision problems, and loss of muscle coordination. There is an association between long-term exposure to CO from cigarette smoke and heart disease, and it affects brain and foetal development (low birth weight in babies), impaired perception and thinking, slowed reflexes and unconsciousness and death (Mathur, 2001; Mishra et al., 2004; E & P, 2007). Montoya et al. (2007) also identified CO exposure with such health effects as ventricular tachyarrhythmias, angina pectoris, and cardiovascular disease. Their study results also highlight potentially hazardous CO exposure, which can be very common in moderate-income countries with cooler climates. It also suggests that the difference between indoor and outdoor temperatures can be correlated with average CO exposure (Montoya et al., 2007; WHO & WPRO, 2004). Increased indoor (domestic) carbon monoxide, especially from the poor quality of stoves (poorly designed, inefficient or defective, incomplete stove release of CO)) and biomass fuel with poor combustion, can decrease the indoor oxygen concentration (WHO & WPRO, 2004). This causes an increased risk of respiratory ill-health for people in developing countries, especially mothers and children. CO also results in systemic effects by reducing the oxygen-carrying capacity of the blood (WHO, 2005c).

The exposure standards/guidelines of WHO and NHMRC values for CO are 110 mg/m^3 for 15 minutes, 60mg/m^3 (50ppm) respectively. The ambient air quality of NEPM for CO is 9ppm (10µg/m^3) for 8 hours (NEPM, 2009). When CO is mixed with blood haemoglobin to form carboxyhaemoglobin (COHb), a level of 2.5% of COHb is not exceeded during exposure for 30 minutes, 30mg/m^3 (25ppm) for 1 hour and 10mg/m^3 (10ppm) for 8 hours (WHO, 1999; WHO, 2000e). The short-term health effects of exposure are dizziness, headache, nausea, and a feeling of weakness.

3.6.2 Carbon dioxide (CO_2) sources, health effects

Carbon dioxide is a natural, colourless, odourless gas whose main sources are the natural environment and the respiration of living beings such as humans, animals and plants (Emmerich and Persily 2001; WHO and UNEP, 2007; NPI, 1999 & 2009). It is also a product of combustion from cooking and heating. LPG, kerosene, or biomass, are all sources of carbon dioxide. Outdoor concentrations are usually between 250-600ppm. Higher (longer-term) exposure can cause nausea, dizziness and headaches (Maroni et al., 1995). However, it has no respiratory symptom effects.

3.6.3 Nitrogen dioxide (NO_2) sources, health effects

Indoor air pollutant studies consider that the NO_2 is the most widely found inorganic pollutant. Its main sources are LPG, tobacco and cooking smoke (indoor combustion sources), heaters using kerosene, gas stoves, and fireplaces using wood, vented appliances, defective installations, and welding. Nitrogen dioxide concentrations normally contribute to respiratory morbidity in children (increased risk of respiratory infections) and adults and exacerbated asthma, that is, increased bronchial reactivity in some asthmatics. Exposure to it can also cause increased airway reactivity, harm or damage to pulmonary function, respiratory symptoms and acute respiratory illness, such as influenza. (Kumar et al., 2008).

3.6.4 Sulphur dioxide (SO_2) sources, health effects

Sulphur oxide (SO_2) is a global problem due to its generation, during combustion, from fossil fuels such as vehicle exhausts, (mobile sources), burning coal, industrial processes such as wood pulping, paper manufacture, petroleum, metal refining and smelting and as a result of geothermal activity (natural sources), (WHO & WPRO, 2004; NPI, 2009), as SO_2. Over 65% or 13 million tonnes per year, of SO_2 is released to the air usually from electric utilities, especially those that burn coal and crude oil (USEPA, 2007). When SO_2 is present in outdoor air, it can affect human health, particularly those suffering from asthma and chronic lung disease (WHO & WPRO, 2004). Generally, even lower indoors SO_2 concentrations can cause respiratory illness, especially acute bronchoconstriction, particularly in children and the elderly, and exposure to high SO_2 can aggravate existing lung and heart diseases and also cause lung malfunction or morbidity. Long-term exposure may result in mortality, generally with a mixture of other pollutants, especially PM and SO_2.

3.7 Organic pollutants

3.7.1 Volatile organic compounds (VOCs) sources, health effects

These are one of the frequent air pollutants, found in high concentrations more in indoor air than in outdoor air, particularly in domestic air (Zhu et al., 2005; Rumchev, Brown and Spickett, 2007). VOCs are one of the most dynamic classes of indoor air contaminants. Their emissions are predominately from road traffic and industrial sources. According to Norback et al. (1995), indoor exposure to VOCs is associated with problems that can affect human airways and cause asthmatic symptoms, including dizziness and lack of coordination. Long time exposure to VOCs can cause heart, liver, lung and kidney disorders (Bauhof and Wensing, 1999; Kriebel et al., 2001).

3.7.2 Formaldehyde (HCHO), sources, health effects

Sources of emissions include catalytic cracking, coking operations and fuel combustion. Natural sources are forest fires, animal wastes, plant volatiles and seawater, and photochemical processes. Its health effects on humans can cause burning sensations in a person's throat, nose, eyes, make the eyes watery and cause difficulty in breathing (NPI, 1999); a discomfort, lachrymation, sneezing, nausea, dyspnoea and finally death (WHO, 2000c).

3.8 Biological pollutants (indoor allergens)

Indoor allergens, including dust mites and cockroaches, animal or pet allergens, pollen and fungi or mould spores, are not covered in the current study.

3.8.5 Condensation and dampness

Condensation occurs when RH is 100% and the air (indoor or outdoor) becomes saturated for it reaches its highest potential to hold water at a given temperature, on any surfaces (because of low ventilation, interior surfaces of homes, wall cavities and window panes), if its temperature is below the dew point of air (Godish, 2001; Zhang, 2004). Condensation and dampness in homes or buildings can have a close association with respiratory symptoms and asthma, especially in mothers and children. It can cause a stuffy odour, and mould, as result of water damage or flooding in the home (Norbach et al., 2000; Zock et al., 2002). The majority of homes in the current study had walls (rough), roofs made of thatch, and their environments were vulnerable to moisture problems. Fewer homes (built of brick and tiles) may have condensation and dampness problems because of the poor structure of the building.

However, these homes suffered from moisture problems, due to the use of cheap building or recycled materials, roof and leaks during rain, floor condensation because of flooding and cold outdoor air and similar conditions. Other "sick" buildings can create poor indoor environments causing the occupants' respiratory illness (Godish, 2001). The majority of temporary homes' (in Tamil Nadu) walls and roofs are made of thatch, (dry knitted coconut leaves). Temporary homes were very common where the current study took place and last, on average, less than 5 years. These dwellings are not free of condensation and dampness, which can vary during the dry and monsoon seasons. The condensation and dampness, of homes are responsible for some respiratory symptoms among mothers and children (Zhang, 2004).

3.9 Environmental tobacco, local cigar (bidi) smoke

Tobacco smoke (tobacco-related cancer contributes to 50% of the burden of cancer and 0.3 million die per year in India (Deogaonkar, 2004)) is the most direct and important source of air pollution which can affect children, adults and the elderly, not only smoking directly, but also inhaling smoke produced by smokers, especially indoors. It is also responsible for increased indoor concentrations of NO_2, CO, formaldehyde, and radon and particulate matter (respirable) (WHO, 2000c). Environmental tobacco smoke (ETS), (also known as passive smoking, or exposure to second-hand tobacco (WHO, 2007a)), local cigar and bidi smoke, in India, are significant sources of IAP (Parikh et al., 2000; Ezzati and Kammen, 2002). Tobacco smoking is an important health risk in both the developed and developing world as the single largest indoor source of fine particles is cigarettes (Brauer and Saksena, 2002; Zhang, 2004). As cited in a WHO report in 1999, 700 million children around the world were exposed to environmental, or second-hand, smoke. Indoor smoking (tobacco or bidi) not only has health risks for the smoker, but can also affect people in the household due to ETS. In India, including Tamil Nadu, about 45% of men and 7% of women (11% of women chew tobacco (Gupta et al., 2003)) smoke cigarettes, 47% to 51% of men, and 52% to 95% of women smoke bidi. Local cigars made by hand, using smoked tobacco, are only for men. Women do not smoke than because of the cigar's size, higher tar and nicotine content, but they are less harmful than cigarettes (Zhang, 2004; Rahman et al., 2005).

Only 7.7% of cigarettes are smoked in India, compared to 49.1% of bidi, which has a higher tar and nicotine content than cigarettes. Bidi is made of about 0.2 g to 0.5 g raw, dried and crushed tobacco flakes rolled by hand in a tendu leaf (Rahman et al., 2005). Environmental tobacco smoke can cause carcinogenic effects in humans, and can produce high numbers of morbidity and mortality from serious health effects at concentrations of 1-10ug/m^3 nicotine. It is also an indicator of ETS. Over half of all children aged 13-15 years are exposed to ETS at home in the majority of countries, especially in developing countries. In addition, health effects due to ETS are acute lower respiratory tract (LRT) infection, middle ear diseases, chromatic respiratory symptoms, (asthma), decreased lung function and acute and chronic respiratory health effects on children, with smokers even in homes with occasional smoking, can measure 0.1-1ug/m^3. No level of exposure to ETS is free of risk, especially to infants and young children because exposure may increase the risk of sudden infant death syndrome (SIDS). It can also cause lymphoma and brain tumours. ETS among adults can cause illness from cancer and cardiovascular and respiratory diseases. There is no evidence for safe exposure concentrations. The cancer risk, if a person smokes, is approximately $1*10^{-3}$ (WHO, 2007a).

3.10 Indoor air climate or meteorological factors

Indoor air quality determined by physical, chemical and biological pollutants, does not only determine IAQ but also the parameters of indoor climate, such as temperature and relative humidity. Temperature (TºC) and humidity (RH%) are very important parameters for enclosed environments such as homes and office buildings. Indoor environmental conditions can vary because of physical factors, including relative humidity, indoor temperature, ventilation, lighting, noise, vibration and/or air movement and activities of households. Most of these factors contribute to adverse health effects, but most attention has been paid to indoor temperature, humidity, and air movement ventilation. Human comfort is associated with indoor temperature, relative humidity and velocity. Indoor air climate determines people’s comfort, especially indoor environmental conditions. In addition, a study shows that there is an association between lower TºC and high RH(%) and respiratory symptoms. (Rumchev, 2001).

3.10.1 Indoor temperature

Indoor temperature (TºC) is also important for indoor air quality; particularly for the domestic environment because it has a very significant effect on health and is an important compounding factor, especially when testing the health effects of air pollutants, indoors and outdoors. Pollutant concentrations can increase during dry and hot seasons (WHO, 1999). During the Indian summer, the indoor temperature in the kitchen can soar to more than 42ºC creating high indoor temperatures and poor indoor air quality. The maximum air temperature can be about 37ºC in winter (Rial and Yoshida, 2002). High temperatures can release some indoor pollutants into the air and these can increase their concentration (Rumchev, 2001). A study in a building has shown that a low indoor temperature can improve perceived IAQ (Tham et al., 2003).

3.10.2 Relative humidity

Relative humidity (RH) ideally should fall within the 40% to 60% range. It does not have any major effects on the toxicity of gaseous pollutants but can change the size of some PM particles, (fine and ultrafine), changing the pattern of deposition of pollutants from smaller to larger airways in the lung (WHO, 1999). Low indoor humidity can improve perceived IAQ (Tham et al., 2003). In addition, humidity lower than 30%-to-40% may cause negative impacts on health, such as throat and skin dryness. A RH of 60% can cause discomfort, headaches and sticky skin (Reinikainen and Jaakkola, 2003; Vortice, 2007).

3.11 Socio-economic factors and indoor air pollution

Recent years have seen recognition of the close inter-relationship between domestic energy (see Appendix D, Figure 1) usage and low-income of households (WHO, 2000d; Pachauri et al., 2005; Gupta and Kohlin, 2005). Households with a lower SES will face a higher risk from polluted air, particularly indoor/domestic air pollution, and a disproportionate burden from elevated exposure. Indoor air pollution from households using biomass (households' use of biomass fuel due to their being unable to afford clean fuel is called “fuel poverty” (WHO, 2000d; Bruce, 2003; Pronczuk de Garbino, 2005)), for their domestic use. The interaction between air pollution and SES was indicated by three measures: types of housing, occupational group and educational attainment (Bell et al., 2005; Ou et al., 2008). Another study has hypothesized that SES and/or poverty level may act as a modifier of the association between air pollution and human health, and also investigated whether income levels can modify the association between people’s health and concentrations of indoor fine particles ($PM_{2.5}$). A study also found that people living in unequal income areas are subject to more air pollution (Charafeddine and Boden, 2008).

A growing number of research studies have shown rising concern regarding the relationship between air pollution and people’s health, with respect to SES (Bell et al., 2005). SES, especially in developing countries where there is no welfare, is an important indicator of the ability and extent regarding how people can protect themselves from major risk factors of disease and poor health, especially due to domestic air quality (DAQ). In Tamil Nadu, those burdened with poor health, suffer because of IAP and predominantly preventable diseases related to poverty and socio-economic inequalities such as belonging to minority groups, or lower castes, or being women or with low employment status (UN, 2001a). In many developing countries and particularly in Tamil Nadu, mothers and women have a very limited degree of control over decision-making, especially if they have lower levels of education (Wagstaff, 2000). According to the energy ladder (see Appendix H, Figures b), when a household’s income increases, its fuel selection also improves from animal dung to electricity (twigs & leaves) >Wood> Charcoal> Kerosene> Coal>LPG, Natural gas to Electricity), (Smith et al., 1994, p. 10; WHO, 2000c, p.11 & WHO, 2005b, p.4). The average annual income for households using kerosene was three times lower than households using LPG and the average education level and age of mothers using LPG was lower as well (Andesen et al., 2005; Padma, 2009).

3.12 Socio-economic status (SES) and health effects

Households from developing countries with low incomes suffer from indoor environmental problems (Santamouris et al., 2007). SES is a major challenge for both developed and developing countries, particularly developing countries (Hornberg and Pauli, 2007). Globalization has brought environmental degradation, worsening socio-economic disparities to both worlds (Ou, Chun-Quant, et al., 2008). The most affected are mothers and children (a study found eight potential mediating factors for socio-economic inequalities in childhood respiratory health such as exposure to other children in infancy, child diet, poor housing conditions, maternal smoking, parental history of asthma, maternal age at child's birth, poor child health at birth and local deprivation (Propper and Rig, 2006)) in poor households from developing countries. Income, employment and educational standards have been shown to be strong predictors of a range of physical health conditions such as respiratory symptoms, coronary disease, schizophrenia and mental health (CMC/Sevanath 2002; Economic Profile Tamil Nadu: Economic Watch (EPTNEW), 2007). If a person is poor, life can be short with hardship and resentment, either absolute or relative poverty and social exclusion or discrimination with poor health, due to not only being poor, but also other social factors, such as belonging to minority groups (WHO, 2003a).

Improving health will also reduce the social gradient in health, the peoples' living conditions and the environment in which they live and work which can influence their health. Poor, social and low economic conditions can affect children throughout their lives. Therefore, the health impact of early development and education for children can last a lifetime (WHO, 2003b). Child poverty and social inequality, mainly in these countries, are also growing both in scope and in complexity (Hornberg and Pauli, 2007). According to Horberg and Pauli (2007) in Germany, the child poverty rate for children and adolescents in 2004 was 1.7 million and in 2005 was 1.5 million (UNICEF, 2005). From low SES families, children's health, both directly and indirectly, can be affected because of residential segregation, poor neighbourhoods with much poverty and substandard housing and poor physical, chemical and social environmental living conditions. Socio-economic status or factors can modify children's susceptibility and exposure to environmental hazards, particularly from very low-income families (Hornberg and Pauli. 2007). There is a strong association between social equality and social integration and people's health. When the society is diverse with different ethnic groups, densely over-populated, with rapid but unequal economic development, this (social and economic inequality) is detrimental to the health of poor people (see Appendix G, Figure 1).

In India, because of growing socio-economic inequality, the health of the poor population has been affected (Deogaonkar, 2004). The most vulnerable people, particularly, are the rural poor households who predominantly use biomass fuel for cooking, boiling water and space-heating in poorly-ventilated kitchens or houses (Ambrose, 2005; Koyuncu and Pinar, 2007). Poverty and the broader term 'SES' are significant determinants of health, especially of many respiratory diseases and symptoms (Hegewald and O' Crapo, (2007). Poverty is also one of the main determinants of poor health and it can be a major cause of disease and a short lifespan. One's SES and/or poverty level (see Appendix K, Figure 1a) determines health status. Mortality occurs at high rates in groups with poor or lower SES. The factors that are classified as social evils that directly influence health are social aid organization, early life events, life-course social gradients, high unemployment, social support and cohesion, poverty, food supply, social exclusion, and health behaviours of individuals (Gupta and Kumar, 2007). The effects of economic and social disparity on the health of a society, particularly with low SES, or people from a poor community or the under-privileged, are great. Socially under-privileged populations, such as scheduled castes, are also unable to get good healthcare, because of geographical, social and/or cultural, economic or gender-related distances (Deogaonkar, 2004). Health improvements for the poor and reducing poverty are two sides of the same coin. If the poor can enjoy better health, they can take advantage of economic opportunities, which can improve their SES levels, a low income adversely affects the health of children because social factors are fundamental elements of the causal pathways to health and disease (WHO, 2008).

In poor areas, a microfinance loans program with nonfinancial interventions, encouraging poor people to select higher-value occupations could reduce poverty impacts (Shaw, 2004). “Environment and the poor” impacts could be categorized into socio-economic, geographic, demographic and cultural (Pulhin, 2001). The majority of poor people die early especially in developing countries. According to Cameron and Williams’ (2005) study, the general health status of children from poor families is compromised by their families’ level of SES. Poor health negatively affects children’s academic achievements, which perpetuates the cycle of poverty. The vertical social stratification, such as parents’ education, occupation and/or family income continues to play a significant part as social class gradients in the health status of children (Hornberg and Pauli, 2007).

According to Hornberg and Pauli, (2007), low SES was responsible for low birth weight, increased neo-natal mortality, injury rates, speech and motor disorders, physical neglect, risk of disabilities, chronic diseases such as childhood diabetes, and lower developmental scores, especially among children. Caused by life expectancy, most diseases are more common further down the social ladder, especially in a poor society. These people face at least twice the risk of illness and early death as those near the top. Poor health has direct effects on poor people and it can be compromised indirectly by living with a community that has high unemployment, poor quality of housing, limited access to social and health services and poor quality environment (WHO, 2003b).

According to the WHO, there are five key areas, which can reduce poverty and/or improve the health of the poor in these countries; economic development at community level; improving agriculture; macroeconomic, environmental and infrastructure projects; education and food policy (WHO, 1998). Concentrating on specific targets in areas of poverty alleviation, or reduction of poverty, includes education at every level, promotion of gender equality, improvement in maternal health, reduction of childhood mortality and prevention of infectious disease, environmental sustainability and partnerships at local, national and international levels (government and non-governmental organisations (NGOs), aid agencies) and global partnerships for development (Gupta and Kumar, 2007). Reducing poverty, particularly in vulnerable groups, can ensure future economic growth and through this, poverty reduction and “better health for all” (AusAID, 2005, p.5).

Health policy must tackle the social and economic determinants of the health of the poor. The reduction of risks associated with indoor air pollution for socially-disadvantaged households and/or populations should be a high priority in households’ health and environmental policies (Ou et al., 2008). O’Neill et al. (2003), after reviewing numerous studies, concluded the findings were, according to the level of socio-economic factors used, at either the individual or contextual-level. The studies at individual-level found strong effects of air pollution among those with lower SES (Krewski, et al., 2000; Pope et al., 2002). The studies using contextual-level SES, found mixed results (O’Neill et al., 2003; Jerrett et al., 2004).

3.13 Indoor air pollution management

Moving from biomass fuel to cleaner fuel, especially for domestic use, can reduce indoor air pollutants. LPG, or electric power, can potentially yield the largest reduction in indoor air pollution. It can also reduce the environmental impact of energy of the stoves’ production and fuel consumption in general (WHO and UNEP, 2007). Improving ventilation systems and the location of stoves can also reduce indoor air pollution. Improving the SES, is one of the significant predictors of cooking fuel choice, and increasing awareness amongst mothers and grandmothers to keep their small children and grandchildren away from kitchens, can avoid constant contact with fires and indoor smoke (Andresen et al., 2005; Viseanathan & Kumar, 2005; WHO and UNEP, 2007), (see Appendix L, Photos 2b).

Trends in household fuel use can be easily discussed by reference to the conceptual framework of the energy ladder (Smith et al., 2004; Gupta and Kohlin, 2005). As a household moves up the ladder, the efficiency, cleanliness, and convenience of the fuels tend to increase, along with rising costs. (Smith et al., 2004). Placement of stoves at waist height with flue (see Appendix L, Photo 4a), can also produce cleaner indoor air and significantly improve the health of mothers and children providing potential benefits to the surrounding house environment. Although outdoor ultrafine particle concentrations have a significant impact on the concentrations of indoor ultrafine particles, the latter can be higher than outdoor levels of particles in most cases (Von Schirnding, 2000; WHO, 2006b).

A study found that an efficient and modern ventilation system could reduce indoor air pollution by 27% (Tuomiso, 2005). Improving the ventilation of a house could be achieved at little or no cost and can lead to substantial improvement in indoor air quality and the health of the people who live in it (Wolff, Schroeder & Young, 2001; Muller et al., 2003). However, it can have obvious limitations and often worsens indoor air quality (WRI, UNEP, UNDP and WB, 1999a). Lower levels of humidity can be achieved with good ventilation (Rumchev, 2001, p152). The Nature Conservancy (TNC), which initiated alternative energy sources programmed in 2001 to protect the rich biodiversity in northwest Yemen, used energy strategies such as more efficient stoves using energy sources such as biogas (PG) and solar water heaters (Padma, 2009).

The WHO, the global public health agency, has already been collecting evidence on the impact of households' energy on mothers' and children's health. It is based on their program on household energy and health and rests on four pillars such as documenting the health burden of indoor air pollution and household energy, evaluating the effectiveness of technical solutions and their implementation, acting as the global advocate for health as a central component of international and national energy policies, and monitoring changes in household energy habits over time. This program is already working in seven developing countries (Guatamala, China, Laos, Mongolia, Nepal, Kenya and Sudan) except India (WHO. 2005c; Padhi, Ghosh and Padhy, 2009).

3.14 Summary

Poor indoor air quality is a critical problem and homes are major environments for exposure to indoor/domestic air pollutants. Respiratory symptoms are a significant problem in India and other countries, particularly poor households' of mothers and children in developing countries. Mothers and young children coughing and choking as they cook food using biomass fuel and over traditional three-stone stoves without flues and with insufficient ventilation, are a common sight in poor households' kitchens in developing countries. Also, domestic/indoor air pollution continues to ravage developing countries' poor households due to low SES. Reducing economic and social inequality and social exclusion can lead to greater social cohesiveness and better standards of health and social and economic conditions. This can result in a social gradient in diet quality that contributes to ending health inequalities (WHO, 2003b). Therefore, the current study needed to find out the effectiveness of households' social and environmental problems to reduce the prevalence of respiratory symptoms and other health problems in mothers and children from Tamil Nadu State in India. Finally, this chapter contains abstracts/summaries of similar studied identified in the research that have been reviewed. For articles that appeared more closely associated with the current study, the full text was retrieved and reviewed.

CHAPTER FOUR

METHODOLOGY

4.1 Introduction

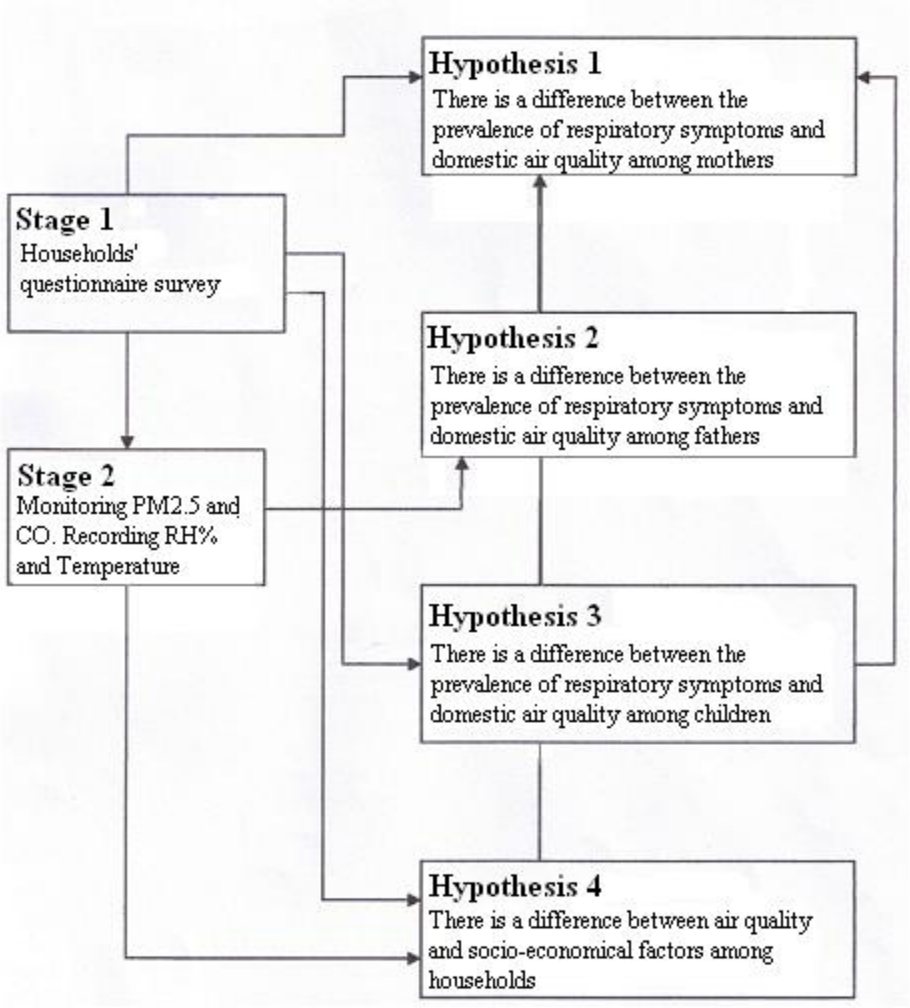
This chapter aims to describe the study design, hypotheses and the various stages of research. It describes homes and the population, sample methods and discusses the questionnaire survey, indoor environmental monitoring, assessment methods and analysis and other methodological issues.

4.2 Study design

In order to achieve the aim and objectives of the current study, a cross-sectional study was conducted. It is a less costly and an ethically acceptable epidemiology research method (Kelsey et al., 1996). Participating households (170) were selected with children under 15-years-of-age (299) because at this age range they do not have a fully-developed immune system, therefore, are more susceptible to respiratory symptoms. This study population samples were randomly selected from one of the districts of Tamil Nadu State in South India, the City of Tirupur, Coimbatore district, with income disparities. The Payne-Sturges and Gee (2006) study suggested that characteristics of the social, physical and built environment contribute to these disparities. The current study explored the influence of the domestic environment and SES and/or poverty levels on respiratory symptoms in mothers and their children through a comprehensive questionnaire covering their health, dwellings, SES factors and monitoring of domestic air pollutants and parameters of indoor climate.

4.3 Study hypotheses and study stages

Figure1: The relationship between study hypotheses and study stages



The main hypothesis of the current study is that there is a relationship between the prevalence of respiratory symptoms affecting mothers and children and SES and/or poverty level and indoor air quality in Tamil Nadu State, in India.

4.4 Study population

(1) Randomly-selected families who are living in four small colonies/communities (with central and local government subsidies such as free lighting, rice and running water) in a peri-urban area of the city of Tirupur in Coimbatore District, Tamil Nadu State, India.

(2) Mothers, fathers and children from 170 households with low SES and/or poverty level.

(3) Children under 15-years-of-age. (children under 15 were selected because this age group is more vulnerable to respiratory symptoms and allergies). Globally, it has been estimated that 3-5 million deaths occur annually in this age group. ARI is the main cause of mortality in children aged less than 5 years.

(4) Households with lower and middle SES (most of the households' families live on a dollar-a-day income, overcrowding is prevalent, mostly in one-room houses, and sometimes cooking is also done in the same room).

(5) Lower SES' households with houses consisting of mud and wood, stone, brick, thatch and tiles. Most of the homes were poorly-built, had poor ventilation and the households mainly used biomass fuel, agricultural residues, wood or kerosene for cooking, heating and boiling water.

4.5 Sample size determination

The current study investigates relationships between respiratory symptoms, SES and/or poverty level, and factors such as house characteristics and kitchen activities associated with indoor air quality. In order to estimate the sample size, researchers have used the prevalence of bronchitis (20%) in India (Amarasiri de Silva et al., 2001), as group one (P1), and group two (P2) as the prevalence of bronchitis of mothers and children in low socioeconomic status families (35%). In a cross-sectional study, the following formula can be used for the calculation of sample size.

$$N = (Z_\alpha + Z_\beta)^2 \frac{p_1(1-p_1) + p_2(1-p_2)}{(p_1 - p_2)^2}$$

N: the number in each group

Z_α = 1.96 (α=0.05)

Z_β=1.28 (β=0.10)

P_1: the proportion of some condition in group 1

P_2: the proportion of some condition in group 2

According to the formula above, 181 subjects for each of the two groups (see above) were needed to detect the difference in prevalence of respiratory symptoms between the two groups, with 90% power of the two-tail test and at 0.05 level of significance, consequently 362 subjects were needed for the current study. As subjects with the exposure to some risk factors may be less than 50% of the population, the researcher planned to recruit 450 mothers and children in order to maintain a sufficient power to detect the difference for those risk factors. The average household has three people (mother and two children, father excluded) in Tamil Nadu in India (UN, 2001b). The current study needed to investigate 150 households to reach the 450 subjects.

For the air quality part, 90 households were randomly selected using a stratified sampling strategy (three major types of houses in Tamil Nadu in India such as stone and brick, clay and mud, and wood and thatch), the house types were stratified and 30 households were selected from each of the three house types, based on questionnaire Section B. In addition to the questionnaire a measured survey of all the mothers and children, indoor pollutants $PM_{2.5}$ and CO were also monitored in 80 households. A study conducted in India reported that the mean indoor concentration of $PM_{2.5}$ was 70µg/m^3 during the dry season and 100µg/m^3 during the wet season, in households using kerosene or liquefied petroleum, gas for domestic fuel (Andresen et al., 2005). With the sample size, this research has 77.4% or 96.7% power to detect a 50% increase of indoor $PM_{2.5}$ levels in the specific households during summer dry, or wet season, respectively (Stata Corporation, 2003).

4.6 Study stages

The experimental part of the current study stages included two parts:

(1) Stage one-Questionnaire survey. The researchers conducted face-to-face interviews with mothers.

(2) Stage two-Domestic air quality assessment. Indoor air pollutants and indoor climate monitoring of $PM_{2.5}$, CO, $T^{o}C$ and RH (%) was carried out.

4.6.1 Stage one-questionnaire survey

The current study used self-reported health (SRH) which has become a conventional method measuring a study population over the last two decades. The utility of this measure derives from multiple factors (CDC, 2001), and includes personal observations of health status, life or sensations and perceptions about one's own body and mind (Jylha et al., 2006). The first method used for data collection was the health of mothers and children; Section B includes questions related to housing and house construction, households' characteristics and activities, especially cooking and indoor smoking and Section C relates to household SES and poverty indicators, including ownership of land and/or house, family income and number of children, (Spengler et al., 2002).

The original questionnaire was in English but for local purposes was translated into the main local language (Tamil). However, some questions had to be re-phrased or modified to improve local understanding. Before starting the survey, a pilot study, which enabled the researcher to recognize any pitfalls beforehand and the way the questionnaire survey should be done, was pre-tested for comprehensibility, appropriateness of language and sensitivity of questions. The nature of the study was explained to households' mothers and they were told what we intended to do. Selected areas were visited a week before the main study began and each household was asked for support, co-operation, and participation. After the mothers had signed a consent form, interviewers filled in the questionnaires during the survey. It was administered before the indoor air sampling. Personal interviewers collected additional data about households' lifestyles, SES and/or poverty level and their quality of life perceptions (Crabble et al., 2004). The questionnaire is attached in Appendix A.

4.6.2. Stage two domestic indoor air pollutants

Stage two included only 80 households for exposure level data collection. Indoor concentrations of $PM_{2.5}$ and CO were measured for 2 hours in the kitchen during cooking and the indoor temperature T^oC and relative humidity RH (%) were noted.

4.7 Domestic environment quality assessment: methods and instruments

4.7.1 Fine particles ($PM_{2.5}$)

A DustTrak (Aerosol Monitor) model 8520, (TSI Inc, 2007), was used for recording fine particles ($PM_{2.5}$) in the indoor air. The particles (2.5-micron diameter in size with a set flow rate to 1.7 litres per minute (L/min) and only samples smaller than the cut-off size were measured and all larger particles were trapped in a grit pot. The DustTrak (TSI Inc, 2007), can be operated in one of two ways, with four size C dry cells or an AC Adapter. The DustTrak has four modes of operation including Survey mode LOG 1, LOG 2 and LOG 3. One of the three LOG modes was used for collecting data but not on the survey mode (TSI Inc, 1997 & 2007). As far as maintenance of the DustTraks was concerned, zero checking and cleaning of the 2.5µm inlet was carried out daily. The sample flow rate was adjusted, very frequently, to 1.7 L/min, and the internal filters and dry cells were replaced when needed (TSI Inc, 1997 & 2007). The DustTrak was placed in the kitchen or where cooking took place (see Appendix M, Photo 1c). The indoor monitoring for $PM_{2.5}$ was conducted for two hours in each household during cooking time.

4.7.2 Carbon monoxide (CO)

For carbon monoxide (CO) monitoring, a Dragger pump model (21/31) sampling pump was used. This is capable of measuring levels of CO between 2.3mg/m^3 to 68.7mg/m^3. Two measurements were taken during cooking, one at the start and the other at the end, for 10 minutes (1 minute ten pump strokes) each time, in each chosen home (see Appendix M, Photo 1a).

4.7.3 Temperature (T^{o}C) and relative humidity (RH)

The indoor temperature and relative humidity were measured using Tinytalk II data loggers such as Temperature Loggers (measurements are from - 40^{o}C to 75^{o}C) and one Relative Humidity Logger (operating range from 0 to 95% RH) in each household, in the kitchen or where cooking was done. The sampling period was two hours in each household. The outdoor daily weather forecast measurements for temperature and relative humidity were obtained from the Indian Meteorological Department (IMD), 2007/2008) (from 12th of December 2007, to 3rd of February 2008) during indoor environmental monitoring (Beru-Be et al., 2004).

4.8 Data analysis

Methodology aims to describe the study design, hypotheses and various stages of research. The tests for appropriate statistics such as descriptive statistics, cross-tabulation, an independent Sample T test, and multiple logistic regressions were conducted later. Firstly, questionnaire data and indoor monitoring of data were entered into a spreadsheet and data screened. The Statistical Package for Social Sciences (SPSS) base version 17.0 for Windows was used (Woolcock and Peat, 1997; Coakes and Steed, 2007). Every collected continuous variable was tested for normality and non-parametric tests. Tests were applied to non-normally-distributed variables. Descriptive statistics and cross-tabulations were generated for demographic factors, such as age, marital status, education level and SES and/or poverty levels. Subsequent data analyses were performed with the level of significance set at a p value less than 0.05 (two-tailed test). Cross-tabulations were also performed between households' characteristics, such as kitchen location, size, and types of fuel used for cooking, types of materials used to build houses, source of lighting, ventilation and health symptoms experienced by the mothers and children. The association between respiratory symptoms and indoor air pollution, household environment conditions and SES and/or poverty levels, were examined by logistic regression analysis. Crude and adjusted variable multiple and odds ratio were obtained/calculated. The statistical analysis described below has two parts, namely the questionnaire survey data and domestic air quality assessment.

4.8.1 Questionnaire survey data

Most variables are categorical variables and are presented as rates (percentage) of their 95% confidence intervals (95% CIs). Continuous variables were analysed as means and standard deviation (SD). An Independent Sample T test was used to analyse the differences between variables (Zhang, 2004; Coakes and Steed, 2007). To measure the associations between two categorical variables Chi–square tests were used. After adjustments for possible confounding variables, logistic models were used for multivariate analyses to estimate the odds ratios and 95% CIs were derived from the logistic model. Respiratory symptoms and other health conditions were chosen as dependent variables and explanatory variables of interest were chosen as independent variables. The p value for trends was computed for several ordinal variables in logistic regression models (Zhang, 2004, p.85; Coakes and Steed, 2007). Finally, multiple logistic regression was done between SES levels and upper and lower respiratory symptoms of mothers and children.

4.8.2 Domestic measurement data

Frequency and descriptive procedures were used for the summary and descriptive analysis of domestic air pollutants $PM_{2.5}$ and CO and physical parameters ($T^{o}C$ and RH%) measured in domestic environments (Bagley, White and Golomb, 2001). Non-parametric tests were used due to the skewness of distribution of $PM_{2.5}$ and CO. Logistic regression analysis (used when outcome measured is categorical and to determine which variables affect the probability of a particular outcome was also carried out for continual and categorical variables of $PM_{2.5}$ and CO in relation to households' characteristics and kitchen activities.

4. 9 Ethical issues

The current study has been cognizant of all the ethical issues. All potential study subjects were given a letter explaining the nature of the current study and if they agreed to participate, they were asked to sign a "consent to participate" form, before interviews were conducted. Because of the voluntary nature of participation, confidentiality and anonymity were protected. Our major consideration was to minimise participant inconvenience and the time they were involved in the current study. The data is strictly confidential. The current study was reviewed and approved by the Curtin University Research Ethics Committee. The privacy of participants was protected at all times and for all concerned individuals and organisations, confidentiality was protected. All data will be kept confidential and no identifiable data will be released. No unauthorised persons will be allowed to access the data. After five years, as required by the National Health and Medical Research Council, the questionnaires will be destroyed. All data will be kept in a university safe place for the required five-year period.

CHAPTER FIVE

RESULTS 1

5.1 Introduction

This chapter describes the results of various statistical analyses of the samples and data obtained from the questionnaire survey and the measurements of indoor air pollutants. The objective of the current study was to investigate demographics, household characteristics, activities of households and respiratory symptoms among mothers and children, in relation to indoor/domestic air quality and families' SES and/or poverty levels. The first section describes the questionnaire survey of the households. It has three main sections: Section A relates to demographic characteristics, which included age, marital status, education levels and employment; Section B includes family health, especially respiratory symptoms of mothers, (fathers) and children, and Section C measures SES and/or poverty levels of households (family income, employment and education, ownerships of house/unit and land as indicators). The survey took place at three different urban localities or colonies in the City of Tirupur, Coimbatore district in Tamil Nadu State, South India, during the months December 2007 to February 2008. The researcher visited the households, the questionnaire was administered and the response was 100%, and there were no invalid responses. These three localities or colonies were located in similar (Tamil Nadu) geographical environments; however, there were differences in lifestyle and levels of SES between these households.

The majority of the households surveyed have very low incomes, low educational standards and less status because most belong to disadvantaged minority groups, such as lower castes and are unskilled workers, especially fathers. In total, 170 households were selected for the current study, which included mothers and children, including male and female children (children were not questioned directly; mothers gave their children's details such as age and their health). Indoor air pollution was monitored in 80 homes and/or kitchens, (where cooking was done). During the survey, observational methods were also used to assess the households' environments, including types of fuel used for cooking, and other household characteristics, such as indoor smoking, types of building materials used to build houses and kitchens, ventilation and the location of kitchens and stoves.

5.2 Demographic characteristics

Participating children were aged between one to 15 and the mothers' ages ranged from 19 to 45 years. Among the total number of 170 households, there were 102 (60%) mothers between 19 and 30 years of age and 68 (40%) mothers between 31 and 45 years of age. The sample included 299 children and 119 (40%) were between one and 5-years-old, 118 (40%) were aged between six and 10 years and 62 (20%) children were aged between 11 and 15 years. The number of children per family ranged from one to five (see Table: 5.1). The 170 households had approximately 702 family members or 4 people per household. About 85% of households had between three and six family members (grandparents and mothers' unmarried siblings, especially mothers' sisters), 8% of the households had between seven and nine family members, and only 7% of households had one or two family members.

Table 5.1 Mothers' and children's demographic characteristics

	Number	**%**
Mother's age		
19 to 30	**102**	**60**
31 to 45	**68**	**40**
Children's age		
1 to 5	**119**	**40**
6 to 10	**118**	**40**
11 to 15	**62**	**20**

Table 5.2 Summary statistics of children aged between one and 15

Total Number of children (n=299)	**Households (n=170)**	
	N	**(%)**
None (less than one and over 15-years-old)	**23**	**(13)**
One child	**46**	**(27)**
Two children	**63**	**(37)**
Three children	**26**	**(15)**
Four children	**11**	**(7.0)**
Five children	**1**	**(1.0)**

According to Table 5.2, the majority, 87% (n=147) of households had children under 15years-old, in 27% (n=46) there was one child and in 37% (n=63) there were two children, 26% (n=15) households had three children, 7% (n=11) households had four children and one household had five children 1% (n=1).

5.2.1 Socio-economic status of households

Indicators used to determine SES and/or poverty levels were family income, employment of mothers, and house/unit and land ownership. The number of house/units and land owners were 38 (22%) and 132 (78%) households did not own their house/unit. The majority of households had either one or two rooms (n=141, 83%). None of the households qualified for a credit facility or loan from their local bank or other financial institution due to their low SES. Because of their low income, households reported getting weekly free rice, sugar and free electricity connection for lighting their homes. As revealed by the questionnaire survey, the numbers of lower income households were 139 (81.8%), that is, they earned less than 1000 Indian rupees, or A$31 per month and the rest of the households: 31 (18.2%) earned between 1000 and 3000 Indian rupees or <A$94 per month. (See Table: 5.2.1 below).

Table 5.2.1 The socioeconomic status of households

Socio-economic status of house holds (n=170)		N	(%)
Do you own the land?	**Yes**	**38**	**(22)**
	No	**132**	**(78)**
Do you own the house/unit?	**Yes**	**38**	**(22)**
	No	**132**	**(78)**
Family income	**Less than A$31**	**139**	**(81.8)**
	Between A$31 and A$94	**31**	**(18.2)**
Employment			
Mothers	**Yes**	**90**	**(53)**
Fathers	**Yes**	**151**	**(89)**

Taking into account parents' employment (mothers') and educational standards of mothers and fathers from the 170 households, just over half of the mothers, 90 (53%) were working full- time and mothers' employment was more secure, more skilled and 80 (47%) mothers stayed at home. Some do part-time or sub-contract textile work from home. The majority of the men, 151 (89%) were employed on a casual or part-time basis, but most of them spent their income on themselves. The statistical analysis showed that 166 mothers (98%) had primary education (Year 7), compared to 156 (92%) fathers. In terms of secondary education (Year 8-12) attendance, three (2%) of the mothers had attended, compared to four (2.5%) of the fathers. However, only one mother in the current study had University education (BA degree) while only ten fathers had less than Year 7 education.

5.2.2 Household and domestic characteristics

Of 170 households, 119 (70%) had a kitchen or stove inside the house (with or without partitions), 51 (30%) had a separate kitchen outside the house or had open air cooking and boiling of water (see Appendix M, Photo 1d & Appendix L, Photo 5c). All the kitchens' walls were made of stone and brick, floors of cement, mud or clay and roofs of thatch or tiles. Seventy-four (43%) had mud floors and 96 (57%)

had cement floors, 60 (35%) had a rough surface finish and 110 (65%) had smooth walls and floors. Most of the inside kitchens' roofs were either thatch (made of coconut leaves) (n=40, 24%) or had tiled roofs (n=120, (71%). According to the study questionnaire, 76 (45%) of the houses had only 1 room, and 65 (38%) houses had two rooms, 18 (11%) houses had 3 rooms, and 10 (6%) had between four and five rooms and only one house had 6 rooms and 90 (53%) had kitchens with no windows. No house or kitchen had carpet.

Table 5.2.2 Household and domestic characteristics

Domestic characteristics (n=170)	Yes, No and types	N	(%)
Windows in the kitchen	**Yes**	**80**	**(47)**
	No	**90**	**(53)**
Types of floor	**Clay and Mud**	**74**	**(44)**
	Cement	**96**	**(56)**
Types of roofs	**Thatch**	**40**	**(24)**
	Iron sheet	**3**	**(2.0)**
	Asbestos	**7**	**(4.0)**
	Tiles	**120**	**(70)**
Types of walls	**Thatch**	**46**	**(27)**
	Wood	**5**	**(3.0)**
	Mud & wood	**9**	**(5.0)**
	Stone & brick	**110**	**(65)**
Number of rooms	**One room**	**76**	**(45)**
	Two rooms	**65**	**(38)**
	Three rooms	**18**	**(10.5)**
	Four, five & six rooms	**11**	**(6.5)**

5.3 Household activities

5.3.1 Indoor smoking (passive smoking)

As revealed by the current study survey, none of the mothers ever smoked but some of the fathers and their visitors did 77 (45%) fathers smoked both indoors and outdoors, and 38 (22%) fathers smoked indoors and 39 (23%) visitors smoked indoors. Most of those interviewed smoked, 60 (35%) smoked local cigars called bidi, followed by 27 (16%) who smoked cigarettes. There were 93 (54.7%) households with non-smokers and there were 77 (54%) smokers.

5.3.2 Kitchen characteristics and activities

The duration of cooking was usually two hours and occurred twice a day. Seventy-eight (46%) houses reported having windows open during cooking and 92 (54%) houses reported that kitchen windows were closed during cooking. There were 143 (84%) houses with doors open and 27 (16%) with doors closed during cooking. Two-thirds of the households, 125 (73%) used biomass fuel, 28 (17%) used LPG and 17 (10%) used kerosene in Indian households, also because of the use of old cooking appliances. Those appliances that are malfunctioning or installed improperly can also cause severe problems (Monkkonen et al., 2005).Three households used diesel for cooking. No coal or electricity was used for cooking in the households surveyed. The mothers' and children's average time spent indoors, including in the kitchen, was about 11 hours, ranging from 3-16 hours.

The types of stove used for cooking were open combustion (a 3-stone open fire), partly open combustion (n=51, (30%) enclosed chamber with no flue (n=118, (63%), enclosed chamber with flue only (n=11, (7%). Every household had electrical connection (81% or 65 homes) for one light bulb and usually in the main bedroom. The kitchen and other areas of the house, used kerosene or lanterns, 9 (11.2%) homes, gas lamps, 6 (7.5%) homes and sometimes candles to complement lighting provided by kerosene and gas lamps.

Table 5.3.2 Kitchen characteristics and activities

Kitchen characteristics and activities (n=170)		N	(%)
Types of stoves used	Open combustion	51	(30)
	Enclosed with no flue	118	(63)
	Enclosed with flue	11	(7.0)
Types of fuel used	Firewood (Biomass)	125	(73)
	LPG	28	(17)
	Others (Kerosene)	17	(10)
Types of lighting	Lanterns	10	(6.0)
	Gas lamp	8	(5.0)
	Electricity	152	(89)
Where cooking done	Indoors	119	(70)
	Outdoors	51	(30)
Open door (during cooking)	Yes	143	(84)
	No	27	(16)
Open windows (during cooking) in kitchen	Yes	78	(46)
	No	92	(54)
Who were present in the kitchen during cooking	Mothers	101	(59)
	Mothers & children	68	(40)
	Whole family	1	(1.0)

5.3.3 Ventilation in the house and/or kitchen

One of the reasons for poor indoor air quality is inadequate ventilation (poor ventilation can increase the levels of exposure to pollution two-fold (Collings et al., 1990)). Poor quality domestic air is mainly due to cooking done inside with biomass fuel and an open stove or with no flue. In addition, no or inadequate ventilation can also increase indoor particulate matter (PM), especially fine particles ($PM_{2.5}$) and carbon monoxide (CO) concentrations. According to the current study, during cooking 27 (16%), households' doors were closed and 143 (84%) doors were open and 92 (54%) windows were closed.

5.4 Indoor air quality assessment in domestic environments ($PM_{2.5}$ and CO)

Out of 170 households, 80 houses were selected for indoor air pollution monitoring. The samples were collected during the two-hour period used for food cooking (either indoors or outdoors) and boiling water. All the indoor and outdoor data, such as indoor temperature $T^{o}C$ and relative humidity RH (%), were collected during cooking time.

5.4.1 Concentrations of domestic air pollutants $PM_{2.5}$

Indoor/domestic fine particles ($PM_{2.5}$), (Table: 5.4 (1)) were recorded from 80 households. The highest $PM_{2.5}$ concentrations of households' were 83.84mg/m^3, the lowest was 0.04 mg/m^3. The mean was 3.8mg/m^3 and the median concentration of $PM_{2.5}$ was 1.18mg/m^3. The WHO Interim Target (IT)-1 of 0.15mg/m^3 (Table: 5.4(1)) for $PM_{2.5}$-$_{10}$ however, indicates that only 11.2% or 9 households met this standard/guideline (see Bar chart 5.4.1a). Forty-one (%) households recorded $PM_{2.5}$ concentrations between 0.15 and 1.5mg/m^3. Twelve (%) households recorded $PM_{2.5}$ concentrations between 1.5 and 3mg/m^3 and three households' concentrations recorded between 3 and 4.5mg/m^3. Four (%) households' concentrations recorded between 4.5 and 6mg/m^3. Finally, 11(%) households' $PM_{2.5}$ concentrations were recorded for over 6mg/$m^{3.}$

Table 5.4 (1) Concentrations of domestic air pollutants $PM_{2.5}$ and CO

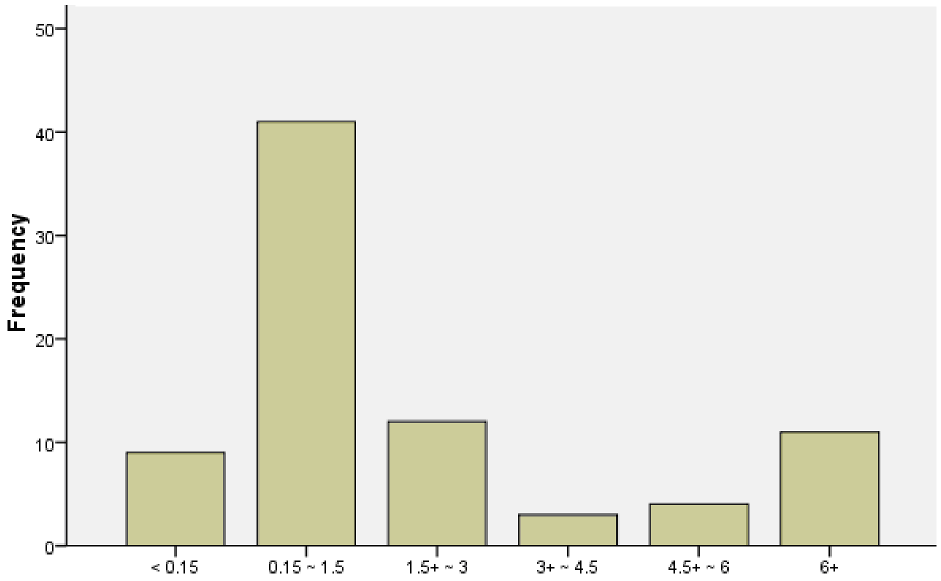
Domestic air pollutants (n=80)	Number of houses	Minimum	Maximum	Mean	Median	(IQR)
$PM_{2.5}$	**80**	**0.4mg/m^3**	**83.84 g/m^3**	**3.80mg/m^3**	**1.18mg/m^3**	**2.41**
CO	**80**	**0.00ppm**	**50ppm**	**4.63ppm/ 8.80mg/m^3**	**0.00mg/m^3/ 0.00ppm**	**7.50**

Table 5.4(2) Mean & median concentrations of $PM_{2.5}$ and CO compared with the WHO, USEPA and NHMRC (Guideline or standard)

Domestic air pollutants (n=80)	Number of houses	Mean concentrations	Median Concentrations	WHO's standard	NHMRC standard
$PM_{2.5}$	**80**	**3.80mg/m^3**	**1.18mg/m^3**	**0.15mg/m^3**	**0.09 mg/m^3**
CO	**80**	**4.63ppm**	**0.00ppm/ 0.00mg/m^3**	**20-40ppm/ 23-46 mg/m^3 for 8 hours)**	**USEPA 35ppm for 1hour**

$PM_{2.5}$ 25ug/m^3 for respectively for 24-hours mean (WHO, 2006a).

Bar chart 5.4.1(1) Range of $PM_{2.5}$ (mg/m^3) indoor concentrations

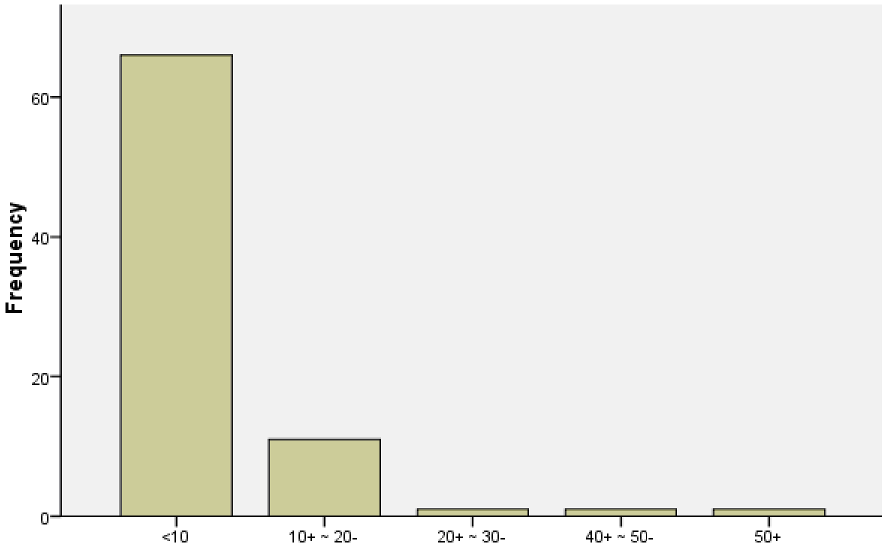


Regrouped $PM_{2.5}$ into 6 groups

5.4.2 Concentrations of domestic air pollutant CO

Indoor cooking carbon monoxide (CO) recorded from 80 houses showed the highest CO concentration of a house was 50 parts per million (ppm), the lowest was 0.00ppm, and the average was 4.63ppm. Only 34 (42.5%) houses had a CO reading and for 46 (57.5%) houses, the reading was zero ppm. Sixty-six houses (82.5%) met the WHO 8-hr guideline (see Bar chart: 5.4.1(2)). Fourteen households (18%) recorded CO concentrations between 10 and 50ppm. Therefore, 82.2% of the households met the WHO's guideline for CO (WHO, 2000b).

Bar Chart: 5.4.1(2) Range of CO (ppm) indoor concentrations



Regrouped CO into six groups

5.4.3 Domestic air climate (temperature and relative humidity)

Indoor or domestic temperatures (T^{o}C) and relative humidity (RH %) were also measured in 80 houses during the sampling of $PM_{2.5}$ and CO (Table: 5.4.3). The current study found that there was a difference between the indoor and outdoor readings of temperature and humidity (the outdoor daily weather forecast measurements were obtained from the Indian Meteorological Department (IMD). In addition, no heating appliances were used in the 80 houses because of the summer season**.** The maximum indoor T^{o}C recorded was 43^{o}C, outdoors 38^{o}C, the indoor minimum was 30^{o}C, and outdoor minimum 23^{o}C. The highest indoor RH% recorded was 82% and the lowest was 33%. The accepted range for T^{o}C is between 19 to 23^{o}C and for RH%, between 40% and 60% and defined thermal comfort as that condition in people, which express satisfaction with the thermal environment (Rumchev, 2001).

Table 5.4.3 Domestic air climate (temperature and relative humidity)

Indoor air climate (n=80)	Number of houses	Minimum	Maximum	Mean	SD
T^{o}C	**80**	**30^{0}C**	**43^{0}C**	**30 ^{0}C**	**3.20**
RH%	**80**	**33%**	**82%**	**52%**	**9.58**

RESULTS 2

Questionnaire Survey

5.5 Introduction

This section will investigate the results of various statistical data analyses of the questionnaire survey. Section A relates to demographic characteristics, Section B includes family health and Section C measures SES and/or poverty levels of the households.

5.5.1 The respiratory symptoms of households

The questionnaire survey investigated respiratory symptoms of mothers, fathers and children. Only two respiratory symptoms (bronchitis and asthma) of fathers were reported (Table: 5.5 (1)). For mothers, wheezing was the most prevalent with 135, (79%) and a cough was the second most prevalent 73 (43%). A third of the mothers reported a constant cough (n=56, (33%). As shown by Table: 5.5 (2), at least one symptom was reported in every mother (n=170, (100%). In the case of children, a cough was the most prevalent respiratory symptom (n=57, (34%), followed by a runny nose (n=39, (23%) and wheezing (n=22, (13%). Furthermore, over a third of the children with a cough, had had it over a long period (n=21, (37%). Table: 5.5 (3) and also shows the number of children who had an allergy (hay fever, itchy-rash and eczema), 19 (11.2%) children had, and 151 (88.8%) did not have, an allergy. Ninety-six children (57%) had at least one respiratory symptom. Ninety-six out of 170 households had at least one occupant who had a respiratory symptom.

Table 5.5 (1) Respiratory symptoms of fathers

Fathers' respiratory symptoms (n=170)	Yes/ No/Unsure	N	(%)
Bronchitis	Yes	7	(4.0)
	No/Unsure	163	(96)
Asthma	Yes	1	(0.6)
	No/ Unsure	169	(99.4)

Table 5.5 (2) Respiratory symptoms of mothers

Mothers' respiratory symptoms (n=170)		N	(%)
Mothers' cough	Yes	73	(43)
	No	97	(57)
Constant cough	Yes	56	(33)
	No	114	(67)
Wheezing	Yes	135	(79)
	No	35	(21)
Shortness of breath	Yes	41	(24)
	No	129	(76)
Bronchitis	Yes	24	(14)
	No	146	(86)
Pneumonia	Yes	7	(4.0)
	No	163	(96)
Chest pain	Yes	61	(36)
	No	109	(64)
Hay fever	Yes	17	(10.0)
	No	153	(90.0)
Overall-mothers (at least one symptom)	Yes	170	(100)
	No	00	(00)

Table 5. 5 (3) Respiratory symptoms and allergies of children

Children's respiratory symptoms (n=170)		**N**	**(%)**
Cough	**Yes**	**57**	**(34)**
	No	**113**	**(67)**
Year cough (n=57)	**<1 year**	**36**	**(63)**
	>1 year	**21**	**(37)**
Wheezing	**Yes**	**22**	**(13)**
	No	**148**	**(87)**
Asthma	**Yes**	**3**	**(6.0)**
	No	**167**	**(94)**
Runny nose	**Yes**	**39**	**(23)**
	No	**131**	**(77)**
Tonsillectomy	**Yes**	**3**	**(2.0)**
	No	**167**	**(98)**
Allergy	**Yes**	**19**	**(11.2)**
	No	**151**	**(88.8)**
Overall-children (at least one symptom)	**Yes**	**96**	**(56.5)**
	No	**74**	**(43.5)**

5.5.2 The frequency of respiratory symptoms of mothers in relation to family (mothers') income

As shown by Table: 5.5.2 more mothers with lower incomes (67 of 139, 48.2%) had a cough compared to only six of 31 (19.4%) with higher incomes and the difference was significant (P=0.003). Mothers in a low-income family are almost four (3.88) times more likely to have coughs than those with higher family incomes. In this case, the odds might be also expressed as "four-to-one" (4:1). Also, according to Table: 5.5.2, more (28%) mothers with lower incomes had shortness of breath, compared with only 6.5% of mothers with higher incomes and the difference was significant (P=0.011). The statistical analysis in a low-income family shows that mothers with lower family income are almost six (5.56) times more likely to have shortness of breath than those mothers with higher family incomes. Finally, more mothers (41.7%) with lower incomes had chest pain compared to only 9.7% of mothers with higher incomes and the difference was significant (P=0.001). Mothers in a low-income family are almost seven (6.67) times more likely to have chest pains than mothers with higher family incomes.

Table 5.5.2 The frequency of respiratory symptoms of mothers in relation to family (mothers') income

Mothers' respiratory symptoms (n=170)	**Low family income≤ AU$31 (n=139) (%)**	**High family income ≥AU31^{+\sim}AU94 (n=31) (%)**	**P value (Chi-square test)**
Cough	**48.2**	**19.4**	**0.003**
Wheezing	**77.7**	**87.1**	**0.242**
Hay fever	**10.1**	**12.9**	**0.643**
Shortness of breath	**28.1**	**6.5**	**0.011**
Bronchitis	**15.8**	**6.5**	**0.175**
Pneumonia	**4.3**	**3.2**	**0.782**
***Tuberculosis**	**1.4**	**0.0**	**0.502**
Chest pain	**41.7**	**9.7**	**0.001**

* it is disease

5.5.3 The frequency of respiratory symptoms of mothers in relation to employment and unemployment

As shown by Table: 5.5.3 below, family income appears to affect the prevalence of respiratory symptoms. Significantly higher prevalence was recorded for coughing (p=0.001), shortness of breath (p=0.003), chest pain (p=0.032) and bronchitis (P=0.005) in mothers with low, compared with higher, incomes.

Table 5.5.3 The frequency of respiratory symptoms of mothers in relation to employment

Mothers' respiratory symptoms (n=170)	**Employed mothers [n=90] (52.9%) (%)**	**Unemployed mothers [n=80] (47.1%) (%)**	**P value (**Chi-square test)
Cough	**56.7**	**27.5**	**0.001**
Wheezing	**75.6**	**83.8**	**0.187**
Hay fever	**14.4**	**6.2**	**0.083**
Shortness of breath	**33.3**	**13.8**	**0.003**
Bronchitis	**21.1**	**6.2**	**0.005**
Pneumonia	**5.6**	**2.5**	**0. 317**
***Tuberculosis**	**1.1**	**1.2**	**0.933**
Chest pain	**43.3**	**27.5**	**0.032**

* it is disease

5.5.4 The frequency of respiratory symptoms of mothers in relation to educational standards

As shown by Table: 5.5.4 below, mothers' educational standards did not have any effect on respiratory symptoms.

Table 5.5.4 The frequency of respiratory symptoms of mothers in relation to educational standards

Mothers' respiratory symptoms (n=170)	Low standard (N=165) (97%) (%)	High standard (N=5) (3%) (%)	P value
Cough	**43.6**	**20.0**	**0.293**
Wheezing	**79.4**	**80.0**	**0.974**
Hay fever	**10.3**	**20.0**	**0.488**
Shortness of breath	**24.8**	**0.0**	**0.201**
Bronchitis	**14.5**	**0.0**	**0.357**
Pneumonia	**4.2**	**0.0**	**0.638**
***Tuberculosis**	**1.2**	**0.0**	**0.804**
Chest pain	**37**	**0.0**	**0.090**

* it is disease

5.5.5 The frequency of respiratory symptoms and allergies of children in relation to households' socio-economic status (SES), (mothers' income)

Frequencies of respiratory symptoms of children were assessed in relation to households' SES and/or poverty levels. Only mothers' income, employment and educational standards were used because the majority of fathers' incomes do not help the family, due to part-time and irregular income and most spent their income on themselves. Therefore, mothers' income was the main determining or contributing factor for the family welfare. Coughs and wheezing appear to be more prevalent among children living in lower income (low-SES) households compared with those from a high-income household and differences were significant. As shown by Table: 5.5.5 (1) below, 54 (39%) children who coughed came from lower income families, of 139, and only three (10%) children from a high-income family. Therefore, lower family income appears to affect the prevalence of the respiratory symptom of children's coughing (p=0.002). For wheezing, 28 (20%) of children who wheezed were from lower income families, where as only one higher-income

(3.2%) child suffered from wheezing (p=0.024), as shown by Tables: 5.5.5 (1). Tables: 5.5.5 (2) showing a child suffering from an allergy (p=0.016).

Table 5.5.5(1) The frequency of respiratory symptoms and allergies of children in relation to households' socio-economic status (SES), mothers' income)

Children's respiratory symptoms (n=170)	**Family low income ≤ AU\$31 (n=139) N (%)**	**Family high income ≥AU\$31$^{+\sim}$AU\$94 N (n=31) (%)**	**P value**
Cough	**54 (39)**	**3 (10)**	**0.002**
Wheezing	**28 (20)**	**1 (3.2)**	**0.024**
Asthma	**3 (2.2)**	**0 (0.0)**	**0.409**
Runny nose	**32 (23)**	**7 (23)**	**0.958**
Tonsillectomy	**5 (3.6)**	**0 (0.0)**	**0.409**
Allergy	**17 (12)**	**2 (6.5)**	**0.356**

Table 5.5.5(2) The frequency of respiratory symptoms and allergies of children in relation to households' SES, (mothers' employment)

Children's respiratory symptoms (n=170)	Unemployed [n=80] (47.1%) N	(%)	Employed [n=90] 52.9%) N	(%)	P value
Cough	23	(28.6)	34	(37.7)	0.213
Wheezing	10	(12.5)	19	(21.1)	0.136
Asthma	00	00	3	(3.3)	0.099
Runny nose	16	(20)	23	(25.6)	0.390
Tonsillectomy	2	(2.5)	1	(1.1	0.492
Allergy	4	(5)	15	(17)	0.016

Table 5.5.5(3) The frequency of respiratory symptoms of children and allergies in relation to households' SES, (Do you own the house/unit?)

Children's respiratory symptoms (n=170)	Do you own the house/unit No (N=132) (77.6%) N	(%)	Do you own the house/unit Yes (N=38) (22.4%) N	(%)	P value
Cough	47	(35.6)	10	(26.3)	0.285
Wheezing	23	(17.4)	6	(15.8)	0.813
Asthma	3	(2.3)	0	(0.0)	0.348
Runny nose	32	(24)	7	(18.4)	0.452
Tonsillectomy	3	(2.3)	0	(0.0)	0.348
Allergy	15	(11.4)	4	(10.5)	0.885

Table 5.5.5 (4) The frequency of respiratory symptoms of children and Allergies in relation to households' SES, (Do you own the land?)

Children's respiratory symptoms (n=170)	Do you own the land? No (N=132)(77.6%) N	(%)	Do you own the land? Yes (N=38)(22.4%) N	(%)	P value
Cough	**56**	**(42.4)**	**1**	**(2.6)**	**0.001**
Wheezing	**29**	**(21.9)**	**0**	**(0.0)**	**0.002**
Asthma	**3**	**(2.3)**	**0**	**(0.0)**	**0.348**
Runny nose	**34**	**(25.8)**	**5**	**(13.2)**	**0.104**
Tonsillectomy	**3**	**(2.3)**	**0**	**(0.0)**	**0.348**
Allergy	**17**	**(12.9)**	**2**	**(5.3)**	**0.189**

5.5.6 The frequency of respiratory symptoms of mothers in relation to households' SES, (Do you own the house/unit?)

As shown in Tables: 5.5.6 (1) only one respiratory symptom (cough) listed for mothers in the current study appears to be significantly related to households' SES in terms of whether they own their own house/unit and land (p=0.048).

Table 5.5.6(1) & (2) The frequency of respiratory symptoms of mothers in relation to the ownership of house/unit or land

Mothers' respiratory symptoms (n=170)	**Do you own the house/unit No (N=132) (77.6%)**		**Do you own the house/unit Yes (N=38) (22.4%)**		**P value**
	N	**(%)**	**N**	**(%)**	
Cough	**62**	**(46.9)**	**11**	**(28.9)**	**0.048**
Wheezing	**105**	**(79.5)**	**30**	**(78.9)**	**0.936**
Hay fever	**7**	**(5.3)**	**11**	**(28.9)**	**0.075**
Shortness of breath	**36**	**(27.3)**	**5**	**(13.2)**	**0.073**
Bronchitis	**2**	**(1.5)**	**22**	**(57.9)**	**0.075**
Pneumonia	**6**	**(4.5)**	**1**	**(2.6)**	**0.601**
***Tuberculosis**	**2**	**(1.5)**	**0**	**(0.0%)**	**0.445**
Chest pain	**50**	**(37.9)**	**11**	**(28.9)**	**0.312**

Mothers' respiratory symptoms (n=170)	**Do you own the land? NO (N=38) (77.6%)**		**Do you own the land? Yes (N=132) (22.4%)**		**P value**
	N	**(%)**	**N**	**(%)**	
Cough	**11**	**(28.9)**	**62**	**(46.9)**	**0.048**
Wheezing	**34**	**(89.5)**	**101**	**(76.5)**	**0.082**
Hay fever	**3**	**(7.9)**	**15**	**(11.4)**	**0.540**
Shortness of breath	**5**	**(13.2)**	**36**	**(27.3)**	**0.073**
Bronchitis	**4**	**(10.5)**	**20**	**(15.2)**	**0.471**
Pneumonia	**2**	**(5.3)**	**5**	**(3.8)**	**0.687**
***Tuberculosis**	**1**	**(2.6)**	**1**	**(0.8)**	**0.345**
Chest pain	**9**	**(23.7)**	**52**	**(38.4)**	**0.075**

* it is disease

RESULTS 3

Indoor air quality assessments

5.7 Introduction

This section describes the relationship between respiratory symptoms and indoor/domestic air quality determined by air pollutants $PM_{2.5}$, CO and T^oC and RH%. In this section, statistical analysis is used to determine the extent to which exposure to indoor air quality, as indicated by concentrations of $PM_{2.5}$ and CO, (CO=0 and CO>0) can influence the prevalence of respiratory symptoms among mothers and children. Further, the relationship between socio-economic status (SES) and the prevalence of respiratory symptoms of mothers and children, was also investigated.

5.7.1 Median concentrations of $PM_{2.5}$ of respiratory symptoms of mothers and children

Since the concentrations of $PM_{2.5}$ do not follow normal distribution, median concentration values will be used. Tables: 5.7.1(1) & (2) show the respiratory symptoms of mothers and children. Although mothers with respiratory symptoms were exposed to higher concentrations of $PM_{2.5}$, no significant differences were established between their concentrations. As far as their children's respiratory symptoms were concerned (Table: 5.7.1(2)), only the presence of a cough was significantly associated with the level of $PM_{2.5}$ concentration ($p=0.035$). The children with a cough, who lived in households where the median $PM_{2.5}$ concentration was $1.39mg/m^3$, were compared to those who lived in households where the median $PM_{2.5}$ concentration was $0.72mg/m^3$, for children who did not cough.

Table 5.7.1(1) Median concentrations of $PM_{2.5}$ (mg/m^3) of respiratory symptoms for mothers

Mothers' respiratory symptoms (n=80)	N	(%)	$PM_{2.5}$ Median	*IQR)	P value (Mann-Whitney)
Cough					
Yes	**47**	**(59)**	**1.3**	**(2.62)**	**0.124**
No	**33**	**(41)**	**0.80**	**(1.67)**	
Wheezing					
Yes	**61**	**(76)**	**1.12**	**(2.52)**	**0.435**
No	**19**	**(24)**	**1.30**	**(2.32)**	
Hay fever					
Yes	**6**	**(7.5)**	**0.45**	**(4.69)**	**0.493**
No	**74**	**(72.5)**	**1.18**	**(2.33)**	
Shortness of breath					
Yes	**23**	**(28.8)**	**1.30**	**(1.15)**	**0.480**
No	**57**	**(71.2)**	**1.32**	**(2.66)**	
Bronchitis					
Yes	**12**	**(15)**	**1.61**	**(3.80)**	**0.278**
No	**68**	**(85)**	**1.24**	**(2.35)**	
Pneumonia					
Yes	**3**	**(3.8)**	**4.86**	**(--)**	**0.396**
No	**77**	**(96.2)**	**1.18**	**(2.24)**	
****Tuberculosis**					
Yes	**2**	**(2.5)**	**2.18**	**(--)**	**0.878**
No	**78**	**(97.5)**	**1.18**	**(2.33)**	
Chest pain					
Yes	**44**	**(55)**	**1.31**	**(2.52)**	**0.720**
No	**36**	**(45)**	**0.76**	**(2.24)**	

*(Inter quartile range) ** it is disease

Table 5.7.1(2) Median concentrations of $PM_{2.5}$ (mg/m^3) and respiratory symptoms and allergies for children

Children's respiratory symptoms (n=80)	**N**	**(%)**	**$PM_{2.5}$ Median**	**(IQR)**	**P value (Mann-Whitney)**
Cough					
Yes	**37**	**(46.3)**	**1.39**	**(2.42)**	**0.035**
No	**43**	**(53.7)**	**0.72**	**(1.84)**	
Wheezing					
Yes	**23**	**(28.7)**	**1.19**	**(4.28)**	**0.244**
No	**57**	**(71.3)**	**1.12**	**(2.18)**	
Runny nose					
Yes	**23**	**(28.7)**	**1.30**	**(2.15)**	**0.410**
No	**57**	**(71.3)**	**1.12**	**(2.54)**	
Tonsillectomy					
Yes	**2**	**(2.5)**	**0.89**	**(--)**	**0.712**
No	**78**	**(97.5)**	**1.18**	**(2.42)**	
Asthma					
Yes	**3**	**(3.8)**	**1.18**	**(2.45)**	**0.595**
No	**77**	**(96.7)**	**0.44**	**(-)**	
Allergy					
Yes	**10**	**(12.5)**	**1.16**	**(4.94)**	**0.449**
No	**70**	**(87.5)**	**1.19**	**(2.28)**	

5.7.2 Median concentrations of CO and respiratory symptoms of mothers and children

The current study investigated when indoor CO (ppm) concentrations less than $10mg/m^3$ (CO<10) and CO concentrations were not equal or greater than CO>=10, from 80 households, no statistically significant association ($p<0.05$) was found between CO concentrations and respiratory symptoms of mothers and children (Tables: 5.7.2 (1) & (2)). However, the mean concentration of CO was $4.63mg/m^3$ or 8.80ppm.

Table 5.7.2(1) Median concentrations of CO (ppm) and respiratory symptoms for mothers

Mothers' respiratory symptoms (n=80)	CO<10				CO>=10			
	N	(%)	Median	(IQR)	N	(%)	Median	(IQR)
Cough								
Yes	37	(56.1)	0.00	(5.00)	8	(72.7)	13.50	(-)
No	29	(43.9)	0.00	(5.00)	3	(27.3)	12.50	(25.00)
Wheezing								
Yes	51	(77.3)	0.00	(5.50)	7	(63.6)	13.75	(7.50)
No	15	(22.7)	0.00	(7.50)	4	(36.4)	13.75	(25.00)
Short of breath								
Yes	19	(28.8)	0.00	(7.50)	4	(36.4)	12.50	(24.38)
No	47	(71.2)	0.00	(2.50)	7	(63.6)	13.75	(7.50)
Bronchitis								
Yes	8	(12.1)	0.00	(5.00)	4	(36.4)	12.50	(-)
No	58	(87.9)	0.00	(5.00)	7	(63.6)	13.50	(6.25)
Pneumonia								
Yes	3	(4.5)	0.00	(-)	00	(0)	(-)	(-)
No	63	(95.5)	0.00	(5.00)	11	(100)	13.50	(7.50)
***Tuberculosis**								
Yes	1	(1.5)	0.00	(-)	1	(9.1)	(-)	(-)
No	65	(98.5)	0.00	(5.00)	10	(92.9)	13.50	(13.75)
Chest pain								
Yes	37	(56.1)	0.00	(5.00)	5	(45.5)	13.00	(11.25)
No	29	(43.9)	0.00	(1.25)	6	(54.5)	13.50	(20.00)
Hay fever								
Yes	5	(7.6)	0.00	(5.00)	1	(9.1)	(-)	(-)
No	61	(92.4)	0.00	(5.00)	10	(90.9)	13.50	(13.75)

* it is disease

Table 5.7.2(2) Median concentrations of CO (ppm) and respiratory symptoms and allergies for children

Children's respiratory symptoms (n=80)	CO<10				CO>=10			
	N	(%)	Median	(IQR)	N	(%)	Median	(IQR)
Cough								
Yes	**30**	**(45.5)**	**0.00**	**(5.00)**	**6**	**(54.5)**	**14.25**	**(33.75)**
No	**36**	**(54.5)**	**0.00**	**(1.88)**	**5**	**(45.5)**	**12.50**	**(4.25)**
Wheezing								
Yes	**51**	**(77.3)**	**0.00**	**(5.00)**	**2**	**(27.3)**	**45.00**	**(-)**
No	**15**	**(22.7)**	**0.00**	**(7.50)**	**8**	**(26.6)**	**13.00**	**(2.12)**
Runny nose								
Yes	**19**	**(28.8)**	**0.00**	**(5.00)**	**2**	**(18.2)**	**31.25**	**(-)**
No	**47**	**(71.2)**	**0.00**	**(5.00)**	**9**	**(81.8)**	**13.00**	**(5.00)**
Tonsillectomy								
Yes	**2**	**(3.0)**	**(-)**	**(-)**	**0**	**(0)**	**(-)**	**(-)**
No	**64**	**(97.0)**	**0.00**	**(4.38)**	**11**	**(100)**	**13.00**	**(5.00)**
Asthma								
Yes	**1**	**(1.5)**	**(-)**	**(-)**	**2**	**(18.2)**	**47.50**	**(-)**
No	**65**	**(98.5)**	**0.00**	**(5.00)**	**9**	**(81.8)**	**12.50**	**(1.75)**
Allergy								
Yes	**9**	**(13.6)**	**0.00**	**(2.50)**	**1**	**(9.1)**	**(-)**	**(-)**
No	**57**	**(86.4)**	**0.00**	**(5.00)**	**10**	**(90.9)**	**13.50**	**(13.75)**

5.7.3 Median concentrations of T^{o}C and RH (%) and respiratory symptoms of mothers

The current study also investigated median levels of T^{o}C and different respiratory symptoms for mothers (Table: 5.7.3 (1)). When T^{o}C was high, more mothers suffered from the following respiratory symptoms: 61 (76%) mothers had wheezing, 47 (59%) mothers had coughs and 44 (55%) mothers had chest pain (p=0.033) and 23 (28.75%) mothers had shortness of breath (p=0.042). It appeared that high humidity significantly affected only chest pain among mothers. Forty-four mothers (Table: 5.7.3 (2)) suffered chest pain (p=0.048), six mothers suffered from hay fever (p=0.017) and three mothers suffered from pneumonia (p=0.029).

Table 5.7.3(1) Median levels of $T^{o}C$ and respiratory symptoms for mothers

Mothers' respiratory symptoms (n=80)	N	(%)	$T^{o}C$ Median	(IQR)	P value (Mann-Whitney)
Cough					
Yes	**47**	**(59)**	**28.68**	**(2.90)**	**0.366**
No	**33**	**(41)**	**29.50**	**(4.43)**	
Wheezing					
Yes	**61**	**(76)**	**29.69**	**(2.30)**	**0.469**
No	**19**	**(24)**	**28.68**	**(4.59)**	
Shortness of breath					
Yes	**23**		**28.50**	**(2.05)**	**0.042**
No	**(28.75)**		**29.60**	**(4.43)**	
	57				
	(71.25)				
Bronchitis					
Yes	**12**	**(15)**	**28.15**	**(2.55)**	**0.037**
No	**68**	**(85)**	**29.50**	**(4.46)**	
Pneumonia					
Yes	**3**	**(3.75)**	**28.30**	**(--)**	**0.389**
No	**77**		**29.40**	**(4.41)**	
	(96.25)				
***Tuberculosis**					
Yes	**2**	**(2.5)**	**28.55**	**(--)**	
No	**78**	**(97.5)**	**29.40**	**(4.39)**	**0.644**
Chest pain					
Yes	**44**	**(55)**	**29.85**	**(4.57)**	**0.033**
No	**36**	**(45)**	**28. 60**	**(2.18)**	
Hay fever					
Yes	**6**	**(7.5)**	**28.10**	**(1.40)**	**0.072**
No	**74**	**(72.5)**	**29.45**	**(4.50)**	

* it is disease

Table 5.7.3 (2) Mean levels of RH (%) and respiratory symptoms for mothers

Mothers' respiratory symptoms (n=80)	N (%)	RH (%) (IQR) Mean	P value
Cough			
Yes	47 (59)	52.45 (11.30)	0.689
No	33 (41)	53.31 (12.72)	
Wheezing			
Yes	61 (76)	52.91 (11.31)	0.855
No	19 (24)	52.49 (12.50)	
Shortness of breath	23 (28.75)	54.48 (17.75)	0.342
Yes	57 (71.25)	52.14 (12.00)	
No			
Bronchitis			
Yes	12 (15)	55.64 (16.25)	0.265
No	68 (85)	52.31 (12.41)	
Pneumonia			
Yes	3 (3.75)	63.58 (--)	0.029
No	77 (96.25)	63.58 (11.17)	
*Tuberculosis			
Yes	2 (2.5)	52.62 (--)	0.955
No	78 (97.5)	52.81 (11.46)	
Chest pain			
Yes	44 (55)	50.85 (14.74)	0.048
No	36 (45)	55.21 (11.75)	
Hay fever			
Yes	6 (7.5)	62.83 (11.18)	0.017
No	74 (72.5)	51.99 (11.22)	

* it is disease

5.7.4 Median levels of T^oC and RH (%) and respiratory symptoms and allergies of children

Median levels of temperature and relative humidity in relation to respiratory symptoms and allergies in children are shown in Tables: 5.7.4 (1) & (2). As revealed by the statistical analysis results, T^oC and RH (%) did not have any significant impact on children's respiratory symptoms.

Table 5.7.4 (1) Median levels of T^oC of respiratory symptoms and allergies of children

Children's respiratory symptoms (n=80)	N	(%)	T^oC Median	(IQR)	P value
Cough					
Yes	**37**	**(46.25)**	**28.60**	**(3.28)**	**0.142**
No	**43**	**(53.75)**	**29.50**	**(4.20)**	
Wheezing					
Yes	**23**	**(28.75)**	**28.50**	**(2.95)**	**0.112**
No	**57**	**(71.25)**	**29.50**	**(4.43)**	
Runny nose					
Yes	**23**	**(28.75)**	**29.50**	**(5.40)**	**0.861**
No	**57**	**(71.25)**	**29.30**	**(3.65)**	
Tonsillectomy					
Yes	**2**	**(2.5)**	**30.30**	**(--)**	**0.478**
No	**78**	**(97.5)**	**29.30**	**(4.39)**	
Asthma					
Yes	**3**	**(3.75)**	**29.60**	**(--)**	**0.790**
No	**77**	**(96.25)**	**29.30**	**(4.41)**	
Allergy					
Yes	**10**	**(12.5)**	**28.45**	**(2.93)**	**0.152**
No	**70**	**(87.5)**	**29.40**	**(4.50)**	

Table 5.7.4 (2) Mean levels of RH (%) of respiratory symptoms and allergies of children

Children's respiratory symptoms (n=80)	**N**	**(%)**	**R/H (%) Mean**	**(IQR)**	**P value**
Cough					
Yes	**37**	**(46.25)**	**52.97**	**(12.03)**	**0.890**
No	**43**	**(53.75)**	**52.67**	**(11.50)**	
Wheezing					
Yes	**23**	**(28.75)**	**54.15**	**(15.80)**	**0.488**
No	**57**	**(71.25)**	**52.27**	**(11.21)**	
Runny nose					
Yes	**23**	**(28.75)**	**52.11**	**(16.63)**	**0.682**
No	**57**	**(71.25)**	**53.09**	**(11.14)**	
Tonsillectomy					
Yes	**2**	**(2.5)**	**53.25**	**(--)**	**0. 976**
No	**78**	**(97.5)**	**52.80**	**(11.39)**	
Asthma					
Yes	**3**	**(3.75)**	**57.67**	**(--)**	**0.246**
No	**77**	**(96.25)**	**52.62**	**11.43**	
Allergy					
Yes	**10**	**(12.5)**	**59.75**	**11.29**	**0.136**
No	**70**	**(87.5)**	**51.87**	**23.94**	

RESULTS 4

Indoor air quality assessment in domestic environments

5.8 Introduction

This section will look at the association between variables of all domestic factors and kitchen activities, which contribute to indoor pollutants $PM_{2.5}$ and CO concentrations, and how the socioeconomic factors and households' characteristics may affect relationships between indoor air pollutants and respiratory symptoms of mothers and children.

5.8.1 House characteristics and kitchen activities

As shown by Table: 5.8.1(1), most of the 80 households: 49 (61.2%) had kitchens inside with or without partitions, whilst 31 (38.8%) had attached or separate kitchens, or open-air cooking, especially for boiling water and for large quantities of food cooking (see Appendix L, Photo 4c). All the closed kitchens' walls and roofs were made of thatch, mud, clay and wood, stone and brick. Forty-five (58.8%) had mud floors and 33 had cement floors, (41.2%). Most of the inside kitchens' roofs were either tile, 50 (62.5%) or thatched, 32 (40%). Forty-eight kitchens (60%) did not have windows and 32 kitchens did have windows.

Table 5.8.1(1) House characteristics and kitchen activities

House characteristics and kitchen activities (n=80)		N	(%)
Types of stoves used	Open combustion	24	(30)
	Enclosed with no flue	56	(70)
Types of fuels used for cooking and boiling water etc	Firewood (biomass)	69	(86.2)
	LPG	6	(7.5)
	Others (Kerosene)	5	(6.3)
Types of lighting	Lanterns	9	(11.3)
	Gas lamp	6	(7.5)
	Electricity	65	(81.2)
Where cooking done	Indoors (kitchen)	49	(61.2)
	Outdoors (kitchen)	31	(38.8)
Open door (during cooking)	Yes	59	(73.8)
	No	21	(26.2)
Open windows (during cooking)	Yes	30	(37.5)
	No	50	(62.5)
Types of walls	Mud & wood	8	(10)
	Stone & brick	40	(50)
	Thatch	32	(40)
Types of roofs	Iron sheet	2	(2.5)
	Asbestos	1	(1.2)
	Tiles	50	(62.5)
	Thatch	27	(33.8)
Types of floor	Clay and Mud	47	(58.8)
	Cement	33	(41.2)
Window in kitchen	Yes	32	(40)
	No	48	(60)

5.8.2 & 3 Domestic factors and kitchen activities contributing to indoor pollutants $PM_{2.5}$ and CO

Domestic factors and kitchen activities contributing to indoor pollutants $PM_{2.5}$ and CO are shown in Tables: 5.8.2 (1) & (2) as domestic factors, particularly kitchen activities, contributing to indoor pollutants. Firstly, types of fuel (biomass) can affect the concentrations of $PM_{2.5}$ and fuel was most significant (p=0.006) and associated with high concentrations of $PM_{2.5}$. Also, there are low concentrations of $PM_{2.5}$ when kitchen windows are opened (p=0.036). Finally, types of roofs (thatch) and floors (clay/mud) of cooking places can also affect the concentration of $PM_{2.5}$ (p=0.033). There is no significant correlation between the indoor air pollutant CO and kitchen activities.

Domestic factors and kitchen activities contributing to high (>=1.5mg/m^3) concentrations of indoor pollutant $PM_{2.5}$ are shown in Table: 5.8.3 (1)). As revealed by the statistical analysis, the factors significantly associated with an increased likelihood of having a high (>=1.5mg/m^3) indoor pollutant $PM_{2.5}$ were: using biomass fuel to cook, not opening kitchen windows when cooking meals, having clay and mud floors and having thatch or mud walls. As far as CO concentrations are concerned, (CO was regrouped in to six groups that is “<10, 10-20, 20-30, 30-40, 40-50, >50” because 46 households had zero reading, (CONweCat1)) there were no significant relationships between this high indoor air pollutant and household factors and kitchen activities. Even though only 34 (42.5%) households had a CO reading, for 46 (57.5%) households, the reading was zero ppm. No table is shown for this analysis (Table 5.8.3 Domestic factors and kitchen activities contributing to indoor pollutants $PM_{2.5}$ and CO (CO new Cat1), table deleted but text under section 5.8.2 Domestic factors and kitchen activities contributing to indoor pollutants $PM_{2.5}$ and CO.)

Table 5.8.2(1) Domestic factors and kitchen activities contributing to median concentrations of PM$_{2.5}$ (mg/m^3)

Domestic factors and kitchen activities (n=80)		N	(%)	PM$_{2.5}$ Median	(IQR)	P value
Types of stoves	Enclosed with Flue	56	(70.00)	0.81	2.64	0.116
	Open combustion	24	(30.00)	1.36	1.42	
Types of fuel	Firewood-biomass	69	(86.25)	1.32	2.34	0.006
	LPG/Others	11	(13.75)	0.16	0.41	
Types of light	Electricity	65	(81.25)	1.18	3.04	0.419
	Lantern/gas	15	(18.75)	0.66	1.30	
Location of kitchen	Outside	31	(38.75)	1.37	1.54	0.098
	Inside	49	(61.25)	0.66	3.35	
Open door	Yes	59	(73.75)	1.09	2.49	0.083
	No	21	(26.25)	1.44	2.70	
Open window	Yes	30	(37.50)	0.46	2.38	0.036
	No	50	(62.50)	1.36	2.27	
Types of roof	Tiles	50	(62.50)	0.88	1.98	0.033
	Thatch/other	30	(37.50)	1.42	4.28	
Types of floor	Clay and Mud	47	(58.75)	1.19	2.19	0.333
	Cement	33	(41.25)	1.09	5.36	
Types of wall	Stone/brick	40	(50.00)	0.62	4.49	0.081
	Thatch/mud	40	(50.00)	1.34	1.80	

Table 5.8.2(2) Domestic factors and kitchen activities contributing to median concentrations of CO<10 and CO>10 (ppm)

Domestic factors and kitchen activities (n=80)		CO<10				CO>10			
		N	(%)	Median	(IQR)	N	(%)	Median	(IQR)
Types of stoves	Enclosed with no flue	47	(71.2)	0.00	5.00	7	(63.6)	12.50	7.50
	Open combustion	19	(28.8)	0.00	2.50	4	(36.4)	13.50	28.12
Types of fuel	Biomass	57	(86.4)	0.00	5.00	10	(90.9)	13.50	13.75
	LPG/Others	9	(13.6)	0.00	3.75	1	(9.9)	(-)	(-)
Types of light	Electricity	53	(80.3)	0.00	5.00	9	(81.8)	13.50	20.00
	Lantern/gas	13	(19.7)	0.00	0.00	2	(18.2)	(-)	(-)
Location of kitchen	Outside	28	(42.4)	0.00	5.00	3	(27.3)	45.00	(-)
	Inside	38	(57.6)	0.00	1.88	3	(72.7)	13.00	2.12
Open door	Yes	46	(69.7)	0.00	5.00	10	(90.9)	13.50	13.75
	No	20	(30.3)	0.00	6.50	1	(9.9)	(-)	(-)
Open window	Yes	24	(36.4)	0.00	1.88	5	(45.5)	13.50	4.25
	No	42	(63.6)	0.00	5.00	6	(54.5)	13.75	33.75
Types of roof	Tiles	38	(57.6)	0.00	5.00	10	(90.9)	13.50	13.75
	Thatch/other	28	(42.4)	0.00	1.88	1	(9.9)	(-)	(-)
Types of floor	Clay and Mud	40	(60.6)	0.00	1.88	6	(54.5)	17.50	33.75
	Cement	26	(39.4)	0.00	5.00	5	(45.5)	1200	1.00
Types of wall	Stone/brick	31	(47.0)	0.00	5.00	7	(63.6)	13.50	2.50
	Thatch/mud	35	(53.0)	0.00	5.00	4	(36.4)	28.75	36.25

Table 5.8.3(1) Univariate odds ratios (95% confidence intervals (CI) for high indoor pollutant $PM_{2.5}$ ($>=0.15 mg/m^3$)

Domestic factors and kitchen activities (n=80)		Crude odds ratio (COR)	95% CI	P value
Types of stoves	**Enclosed with no flue**	**1**	**(0.000, -)**	**0.998**
	Open combustion	**-**		
Types of fuel	**Firewood (biomass)**	**1**	**(0.030, 0.631)**	**0.011**
	LPG/Others	**0.137**		
Types of light	**Lanterns/ Gas lamp**	**1**	**(0.059 4.411)**	**0.540**
	Electricity	**0.509**		
Location of kitchen	**Indoors kitchen**	**1**	**(0.695, 49.333)**	**0.104**
	Outdoor kitchen	**5.854**		
Open door (kitchen)	**No**	**1**	**NA**	**0.998**
	Yes	**0**		
Open window (kitchen)	**No**	**1**	**(0.026, 0.712)**	**0.018**
	Yes	**0.137**		
Types of roof	**Thatch**	**1**	**(0.021, 1.526)**	**0.116**
	Tile	**0.181**		
Types of floor	**Clay and Mud**	**1**	**0.008, 0.575)**	**0.014**
	Cement	**0.068**		
Types of wall	**Thatch/mud**	**1**	**(0.012, 0.864)**	**0.036**
	Brick/Stone	**0.103**		

5.8.4 Upper and lower respiratory symptoms of mothers and children in relation to domestic factors, kitchen activities, and indoors, on concentrations of $PM_{2.5}$ and CO

In the current study, upper respiratory symptoms are identified as a runny nose, coughs and lower respiratory symptoms, wheezing, shortness of breath, asthma, chest pain, and bronchitis. The study looked at upper and lower respiratory symptoms of mothers and children in relation to domestic factors and kitchen activities and concentrations of indoor air pollutants, $PM_{2.5}$ and CO. Based on Table: 5.8.4 (1), mothers living in houses without electricity were more likely (OR=2.984 (95% CI: 1.063 - 8.376)) to have at least one upper respiratory symptom, compared to mothers who lived in houses in which electricity was available. Other factors significantly associated with an increased risk of a mother having at least one upper respiratory symptom were not opening the kitchen windows, having clay and mud floors, having thatch or mud walls and having indoor kitchens.

Table 5.8.4 (1) Univariate odds ratios and 95% CI for mothers having at least one upper respiratory symptom

Domestic factors and kitchen activities (n=170)		**Crude odds ratio (COR)**	**95% CI**	**P value**
Types of stoves	**Open combustion**	**1**	**(0.638, 2.428)**	**0.521**
	Enclosed with no flue	**1.245**		
Types of fuel	**LPG/others**	**1**	**(0.961, 4.076)**	**0.064**
	Firewood (biomass)	**1.9769**		
Types of light	**Electricity**	**1**	**(1.063, 8.376)**	**0.038**
	Lanterns/gas lamp	**2.984**		
Location of kitchen	**Outdoor kitchen**	**1**	**(0.251, 0.951)**	**0.035**
	Indoor kitchen	**0.488**		
Open door (kitchen)	**Yes**	**1**	**(0.563, 2.930)**	**0.552**
	No	**1.285**		
Open window (kitchen)	**Yes**	**1**	**(1.235, 4.331)**	**0.008**
	No	**2.313**		
Types of roof	**Tile**	**1**	**(0.689, 2.597)**	**0.390**
	Thatch/other	**1.338**		
Types of floor	**Cement**	**1**	**(1.206, 4.182)**	**0.011**
	Clay and mud	**2.246**		
Types of wall	**Brick/stone**	**1**	**(1.544, 5.672)**	**0.001**
	Thatch/mud	**2.959**		

Table 5.8.4 (2) Univariate odds ratios and 95% CI for mothers having at least one lower respiratory symptom

Domestic factors and kitchen activities (n=170)		Crude odds ratio (COR)	95% CI	P value
Types of stoves	Open combustion	1	(0.220, 3.411)	0.838
	Enclosed with no flue	0.867		
Types of fuel	LPG/others	1	(0.718, 8.564)	0.151
	Firewood (biomass)	2.479		
Types of light	Electricity	1	(0.144, 9.937)	0.868
	Lanterns/ gas lamp	1.197		
Location of kitchen	Outdoor kitchen	1	(0.218, 3.380)	0.828
	Indoor kitchen	0.859		
Open door (kitchen)	Yes	1	(0.240, 15.934)	0.531
	No	1.955		
Open window (kitchen)	Yes	1	0.425, 4.947)	0.553
	No	1.450		
Types of roof	Tile	1	(0.138, 1.630)	0.236
	Thatch/other	0.474		
Types of floor	Cement	1	(0.270, 3.140)	0.894
	Clay and mud	0. 920		
Types of wall	Brick/stone	1	(0.380, 5.841)	0.567
	Thatch/mud	1,490		

The results in Table: 5.8.4(2) show that domestic factors and kitchen activities did not indicate any association with mothers' lower respiratory symptoms, such as wheezing, shortness of breath, chest pain, and bronchitis.

Table 5.8.4(3) Univariate odds ratios and 95% CI for children having at least one upper respiratory symptom

Domestic factors and kitchen activities (n=170)		Crude odds ratio (COR)	95% CI	P value
Types of stoves	**Open combustion**	**1**	**(1.022, 4.161)**	**0.043**
	Enclosed with no flue	**2.062**		
Types of fuel	**LPG/others**	**1**	**(0.603, 2.440)**	**0.589**
	Firewood (biomass)	**1.212**		
Types of light	**Electricity**	**1**	**(0.245, 1.929)**	**0.477**
	Lanterns/ gas lamp	**0.688**		
Location of kitchen	**Outdoor kitchen**	**1**	**(0.206, 0.790)**	**0.008**
	Indoor kitchen	**0.404**		
Open door (kitchen)	**Yes**	**1**	**(0.732,3.822)**	**0.222**
	No	**1.673**		
Open window (kitchen)	**Yes**	**1**	**(0.891, 3.2084)**	**0.111**
	No	**1.658**		
Types of roof	**Tile**	**1**	**(0.605, 2.297)**	**0.629**
	Thatch/other	**1.179**		
Types of floor	**Cement**	1	**(1.026, 3.551)**	**0.041**
	Clay and mud	**1.909**		
Types of wall	**Brick/stone**	**1**	**(1.407, 5.137)**	**0.003**
	Thatch/mud	**2.688**		

According to Table: 5.8.4(3), the odds of at least one upper respiratory symptom for children living in houses with enclosed stoves with no flue was 2.062 (95% CI: 1.022 - 4.161)), times higher, compared with children who lived in houses with open combustion. Table: 5.8.4(3) also showed children in houses with an indoor kitchen were less likely (OR = 0.404 (95% CI: 0.206 - 0.790)), to have at least one upper respiratory symptom, compared to children who lived in houses with outdoor kitchens, which were either in the open air or enclosed. Also, kitchen floors made of clay or mud (OR=1.909 (95% CI: 1.026-3.551)) and walls built/made of thatch or mud (OR=2.688 (95% CI: 1.407-5.137)), were factors significantly associated with an increased likelihood of a child having at least one upper respiratory symptom. Cooking indoors allows pollutants to be deposited on rough clay floors and thatched walls and roofs and can increase the indoor temperature.

Table 5.8.4 (4) Univariate odds ratios and 95% CI for children having at least one lower respiratory symptom

Domestic factors and kitchen activities (n=170)		Crude odds ratio (COR)	95% CI	P value
Types of stoves	**Open combustion**	**1**	**(0.724, 4.960)**	**0.193**
	Enclosed with no flue	**1.895**		
Types of fuel	**LPG/others**	**1**	**(0.587, 4.066)**	**0.379**
	Firewood (biomass)	**1.545**		
Types of light	**Electricity**	**1**	**(0.120, 2.547)**	**0.448**
	Lanterns/ gas lamp	**0.554**		
Location of kitchen	**Outdoor kitchen**	**1**	**(0.184, 0.932)**	**0.033**
	Indoor kitchen	**0.415**		
Open door (kitchen)	**Yes**	**1**	**(0.902, 5.945)**	**0.081**
	No	**2.316**		
Open window (kitchen)	**Yes**	**1**	**(0.825, 4.324)**	**0.132**
	No	**1.889**		
Types of roof	**Tile**	**1**	**(0.350, 2.058)**	**0.716**
	Thatch/other	**0.848**		
Types of floor	**Cement**	**1**	**(1.006, 5.032)**	**0.048**
	Clay and mud	**2.250**		
Types of wall	**Brick/stone**	**1**	**(0.950, 4.692)**	**0.067**
	Thatch/mud	**2.111**		

The results based on Table: 5.8.4 (4), showed the odds of having at least one lower respiratory symptom for children living in houses with indoor kitchens were (OR= 0.415 (95% CI: 0.184 - 0.932)), decreased by 58.5%, compared with children who lived in houses with enclosed or open-air outdoor kitchens. Again, when the kitchen floor is made of clay or mud (OR=2.250 (95% CI: 1.006 - 5.032)), the likelihood of children having at least one lower respiratory symptom is increased by 125%, compared to children who lived in houses with cement floors.

5.8.5 SES factors associated with upper respiratory symptoms (cough) in mothers

As Table: 5.8.5 (1) shows, mothers who owned houses were less likely (OR=2.554 (95% CI: 1.115 - 5.852)), to have upper respiratory symptoms, compared to those mothers who did not own houses. Another factor significantly increased the likelihood of having at least one upper respiratory symptom was mothers', occupation. Mothers who had factory or building jobs were more likely (OR=3.004, 95% CI = (1.522-5.930) to have at least one upper respiratory symptom than those mothers who had casual or home duty work.

Table 5.8.5(1) SES factors associated with having at least one upper respiratory symptom (cough) for mothers

Variable	Crude odds ratio (COR)	Adjusted OR (AOR)	95% CI
Mothers' qualification **Low**	**1**	**1**	
High	**0.323**	**0.932**	**(0.074, 11.674)**
Family income **<1000 rupees (INR)**	**1**	**1**	
<3000 rupees	**0.258**	**0.435**	**(0.148, 1.282)**
Own the land **No**	**1**	**1**	
Yes	**0.460**	**0.591**	**(0.233, 1.497)**
Own the house **No**	**1**	**1**	
Yes	**2.174**	**2.554**	**(1.115, 5.852)**
Mothers' occupation **Casual/home duty**	**1**	**1**	
Factory/building	**3.448**	**3.004**	**(1.522, 5.930)**
Number of children	**0.884**	**0.967**	**(0.725, 1.290)**

-2 log likelihood=206,429a, d.f =6

5.8.6 SES factors associated with lower respiratory symptoms in mothers

Table: 5.8.6(1), based on the sample collected shows there were no significant SES factors found to be associated with mothers' lower respiratory symptoms

Table 5.8.6(1) SES factors associated with lower respiratory symptoms in mothers

Variable	Crude odds ratio (COR)	Adjusted OR (AOR)	95% CI
Mothers' qualification **Low** **High**	**1**	**1**	
	0.258	**0.225**	**(0.010, 5.333)**
Family income **<1000 rupees (INR)** **<3000 rupees**	**1**	**1**	
	0.570	**0.349**	**(0.060, 2.019)**
Own the land **Yes** **No**	**1**	**1**	
	0.330	**0.157**	**(0.013, 1.946)**
Own the house **Yes** **No**	**1**	**1**	
	0.314	**0.373**	**(0.102, 1.371)**
Mothers' occupation **Casual/home duty** **Factory/building**	**1**	**1**	
	1.378	**1.231**	**(0.333, 4.554)**
Number of children	**0.938**	**0.934**	**(0.545, 1.599)**

-2 log likelihood=749.108, d.f =6

5.8.7 SES factors associated with upper respiratory symptoms in children

According to Table: 5.8.7(1), the prevalence of upper respiratory symptoms in children increased by 40% when the family has one more child (OR=1.403), 95% CI=(1.48, 1.879). Therefore, family size was one of the contributing factors of respiratory symptoms. Other factors significantly associated with an increased risk of a child having at least one upper respiratory symptom, were parents not owning the land and the house.

Table 5.8.7(1) SES factors associated with upper respiratory symptoms in children

Variable	Crude odds ratio (COR)	Adjusted OR (AOR)	95% CI
Mothers' qualification Low	1	1	
High	0.348	1.179	(0.102, 13.614)
Family income <1000 rupees	1		
(INR) <3000 rupees	0.432	1.003	(0.334, 3.013)
Own the land No	1	1	
Yes	0.156	0.115	(0.035, 0.371)
Own the house No	1	1	
Yes	1.698	2.369	(1.045, 5.370)
Mothers' occupation Casual/home duty	1	1	
Factory/building	1.333	1.253	(0.634, 2.477)
Number of children	1.240	1.403	(1.048, 1.879)

-2 log likelihood=202.839, d.f=6. Children

5.8.8 SES factors associated with having lower respiratory symptoms in children

Finally, Table: 5.8.8(1) shows that a family with more children is likely to have a higher risk of having lower respiratory symptoms in the children. The risk increased by 63% when the family had more than one child (OR=1.629 95% CI=1.128 - 2.352). The risk of children having lower respiratory symptoms from families with high income decreased significantly by 88.5% compared to low family income households' children (OR = 0.115 (95% CI: 0.014 - 0.943)).

Table 5.8.8 (1) SES factors associated with having lower respiratory symptoms in children

Variable	Crude odds ratio (COR)	Adjusted OR (AOR)	95% CI
Mothers' qualification			
Low	1	1	
High	n/a	n/a	(n/a)
Family income			
<1000 rupees	1	1	
<3000 rupees	0.126	0.115	0.014, 0.943)
Own the land			
No	1	1	
Yes	n/a	(n/a)	(n/a)
Own the house			
No	1	1	
Yes	1.185	1.287	(0.459, 3.608)
Mothers' occupation			
Casual/home duty	1	1	
Factory/building	2.00	1.952	(0.797, 4.783)
Number of children	1.402	1.629	(1.128, 2.352)

2 log likelihood=142.758, d.f=4

5.9 Summary

The data used for analysis in this chapter was collected through a questionnaire survey, which included households' demographic information and their health, particularly respiratory symptoms in mothers and children. Households' SES factors such as family income, employment, and educational level, ownership of house/unit and/or land and the relationship between SES and respiratory symptoms of mothers and children, were also investigated. Indoor air pollutant data was also collected through the monitoring of $PM_{2.5}$ and CO and physical parameters such as indoor temperature (TºC) and relative humidity (RH). This chapter shows the various SPSS statistical analyses used to achieve the current study's aims, such as SES and/or poverty levels, which may be associated with respiratory symptoms in mothers (fathers) and children. The result of the current study also showed that there may be significant association with risk factors and the prevalence of respiratory symptoms.

Summaries of the findings below were seen to be significant:

More mothers with lower incomes had a cough compared to only a few with higher incomes and the difference was significant. They are almost four times more likely to have coughs than mothers with higher incomes and almost six times more likely to have shortness of breath than mothers with higher family incomes. Also, mothers with lower incomes had chest pain six times more than mothers with higher incomes. Mothers who lived in households where the $PM_{2.5}$ concentration was high, the prevalence of respiratory symptoms was also high and when the $PM_{2.5}$ concentration was low, the prevalence of respiratory symptoms was also low. When T^oC was high, more mothers suffered from wheezing and cough. It appeared that high humidity significantly affected only chest pain among mothers. There is no significant correlation between CO concentrations and mothers' respiratory symptoms.

Mothers had at least one upper respiratory symptom, due to inadequate house ventilation, their houses having clay and mud floors, thatch or mud walls and indoor kitchens. Mothers who owned houses were less likely to have upper respiratory symptoms compared to mothers who did not own houses. Another factor that significantly increased the likelihood of their having at least one upper respiratory symptoms was a mother's occupation. Mothers who had factory or building jobs were more likely to have at least one upper respiratory symptom compared with mothers who had casual or home duty work. There were no significant SES factors found to be associated with mothers' lower respiratory symptoms.

Risk factors significantly associated with an increased risk of a child having at least one upper respiratory symptom were parents not owning the land and the house. The children with a cough lived in households where the median $PM_{2.5}$ concentration was high, compared to children who did not cough in households where the median $PM_{2.5}$ concentration was low. There is no significant correlation between CO concentrations and children's respiratory symptoms. Children in houses with an indoor kitchen were more likely to have at least one upper respiratory symptom compared to children who lived in houses with outdoor kitchens. Kitchen floors made of clay or mud with walls made of thatch or mud were factors significantly associated with a child having at least one upper respiratory symptom. Again, when the kitchen floor was made of clay or mud, there was a strong likelihood of children having at least one lower respiratory symptom, compared to children who lived in houses with brick walls, tile roofs and cement floors.

Families with more than one child are likely to have a higher risk of the children having upper (40%) and lower (63%) respiratory symptoms. Therefore, it is seen to be family size (more than one child) was one of the contributing risk factors for the prevalence of respiratory symptoms. The risk of children having lower respiratory symptoms from families with a high income decreased significantly by 88.5% compared to low family income households' children.

Of the type of fuel that can affect the concentrations of $PM_{2.5,}$ biomass was the most significant. There were low concentrations of $PM_{2.5}$ when kitchens had more windows and were open. Types of roofs and floors can also affect pollutant concentrations because mud and clay floors and thatch roofs can retain old and new smoke. There is no significant correlation between indoor air pollutant CO and kitchen activities. Poor quality domestic air is mainly due to cooking done inside with biomass fuel and an open stove or no flue with inadequate ventilation. Finally, major risk factors for mothers' and children's respiratory symptoms are households' SES and/or poverty levels.

CHAPTER SIX

DISCUSSION

6.1 Introduction

Respiratory symptoms are a common health burden among the poor and low socio-economic status population, especially among mothers and children from developing countries. SES is usually measured in terms of level of income, education and occupational prestige within countries and across countries (Gehring et al., 2006). The income threshold varies from one country to another within a country, and household-to-household (Hegewald and O'Crapo, 2007). Poverty and lower social status are also associated with family size, crowded living conditions, less access to health care, nutritional deficits, higher rates of indoor and passive smoking, exposure to indoor (biomass fuel smoke) and environmental pollutants and a stressful living environment. Lower socio-economic status and/or poverty levels significantly affect people and their health status (WHO, 2008). SES encompasses other elements in addition to a family's or individual's income and is also defined as social and economic standing and is the measure of a family's or individual's social and economic position or rank in a social group (Hegewald and O'Crapo, 2007). Lower family income, according to the World Bank, (2007), is an income of US$2 a day, and extreme poverty is an income of less than US$1 a day and can be a risk factor for impoverishment or poverty levels of households that can deplete health. Poor health can disrupt household income, be a major drain on it and can also lower the social level (WHO, 2005a).

The economic consequences of poor health, especially for working members of households, can be substantial. Mothers and children from high-income households were seen to have less significant effects of respiratory symptoms than mothers and children from low-income households. This chapter discusses the findings of the current study in terms of implications for health status, peoples' SES and/or poverty levels, and respiratory symptoms of mothers and children from poor households from Tamil Nadu, in South India. It takes into account the published works in this area and how the current study findings are in agreement with the findings of similar studies/research in the same area and ends with a discussion about households' SES and/or poverty levels, house and kitchen characteristics, concentrations of $PM_{2.5}$ and CO and their relationship to indoor air pollutants, respiratory symptoms of poor households' mothers' and children's groups being studied. The reliability assessment of the questionnaire and validity of the current study are also discussed in this chapter.

6.2 Reliability assessment of the questionnaire

In order to assess the reliability of the questions appropriate to South Indians of Tamil Nadu, the questionnaire was modified to suit that particular society because in India, culture can vary from State-to-State and even within the State. To confirm the reliability of the questionnaire, some parts relating to the health section and house structure section had to be verbally re-phrased or modified during interviews. Statistical analyses used for assessing the reliability of the questionnaire were proportions of agreement (%), the Kappa coefficient and the McNamara test. However, the Kappa is unstable and inappropriate as a reliability assessment in the case of a large proportion of agreement.

6.3 The validity and limitations of the study

Threats to validity may arise from the potential for bias, particularly in the selection of the current study's population and the collection of data. The following examples provide an overview of the different threats to the validity of the current study. It was realised that the choice of the studied population could generate selection bias. A further source of selection bias of the current study may have arisen from some households' refusal to participate in the current study (less than 1%).

To avoid or minimize the possibility of bias, several strategies were employed during the data collection. Before the main questionnaire survey, the researcher and interviewers made personal visits to mothers and children of households and built a personal relationship between themselves and the households, particularly with mothers. In some cases, ages were determined only by word-of-mouth, as some mothers had neither a birth certificate nor a ration book that could be used to check their age and this might have introduced a bias in the information. In terms of external validity, the current study's results may have national and international limitations for generalization. One of the major limitations with cross-sectional studies is that time sequence cannot be observed. Mothers' and children's respiratory symptoms were self-reported symptoms, not clinically diagnosed as no medical tests carried out. Therefore, the validity of the diagnosis of respiratory symptoms in mothers, and especially in children, has also introduced a bias in the information. Some questions were modified to the local dialect, but still some health questions might have introduced recall or observation biases about children's respiratory health status or conditions.

There are limitations to the current study results that may affect external validity because some mothers may not have understood some questions. Questions such as those relating to the structure of houses/kitchens and health status, especially of children, may have required clarification so the interviewer asked further questions to ensure a valid response. Another limitation is that the current study was restricted to only one season. Because of time and resource limitations, data collection was conducted only in the summer/dry season, which did not provide the opportunity to compare exposure levels between different seasons, dry and wet. A further limitation was caused by one season's (dry) measurements of $PM_{2.5}$, CO and temperature ($T^{o}C$) and relative humidity (RH%), because the dry season was expected to represent high exposure levels of these indoor air pollutants. To control confounding variables of the current study, the Mantl-Henzel method was applied.

Standardisation and the logistic analysis that provided adjusted estimate of the odds ratio were used. Multivariable analysis was used in order to control extraneous variables. The collected data was checked and tested and re-tested for reliability, otherwise the results could have been eroded. Chronic exposure to domestic air pollution is significantly associated with respiratory symptoms due to the effects of social, demographic, and lifestyle confounders, which have been considered in the current study.

6.4 Discussion of the findings

6.4.1 Risk factors for respiratory symptoms

The discussion is divided into four parts based on four types of risk factors for respiratory symptoms in mothers and children in Tamil Nadu in India. The first part examines house or kitchen characteristics and concentrations of $PM_{2.5}$ (fine particulate matter, with an aerodynamic diameter less than or equal to 2.5µm (Charafeddine and Boden, 2008)) and CO. The second part discusses house or kitchen characteristics and health effects on mothers and children. The third part focuses on $PM_{2.5}$, CO, T°C and RH% health effects on mothers and children. The final part focuses on households' SES and/or poverty levels and health effects of respiratory symptoms on mothers and children. Finally, the results of similar study articles identified in the research were reviewed. Articles that appeared more closely associated with the current study results were retrieved and compared, contrasted and discussed.

6.4.2 House and kitchen characteristics associated with indoor air pollutants ($PM_{2.5}$ and CO)

Other literature reviews claim there are numerous sources of indoor air pollutants contributing to indoor pollution. $PM_{2.5}$ is considered as the most strongly associated with observed mortality and morbidity (Suh et al., 2000). The current study found that the types of materials used for building homes, kitchens, locations of kitchens, types of fuel and types of stoves (improved stoves are 1.7 times more efficient than traditional stoves used for cooking (Oanh, et al., 2005; Gopalan and Saxena, 1999)), (see Appendix I, Figures 1a & 1b) households' activities and natural ventilation, all had an influence on exposure levels to pollutants. However, in the absence of indoor sources, indoor/outdoor pollutant ratios will be less than or equal to one (Lee et al., 2001; Ho et al., 2004) and can vary according to location, characteristics of the house, and activities of households (Padma, 2009). Massey et al. (2009) study show that $PM_{2.5}$ concentrations rose as the result of households' activities. Again, indoor pollutant emissions can vary according to natural ventilation and the air exchange rate which can increase or decrease concentrations of indoor pollutants (Rumchev, 2001). A study from India found that it is possible to reduce indoor air pollution in households by improving ventilation and decreasing penetration of outdoor particles (Monkkonen et al., 2005). The study of Massey et al. (2009) confirmed that average $PM_{2.5}$ concentrations measuring 0.18mg/m^3 from Indian rural homes were higher than the WHO guideline for $PM_{2.5}$ of 8 hours. It was seen that the indoor air concentrations in the average rural home, $PM_{2.5}$ was 5-8 times greater than the prescribed standards of the WHO guidelines and higher than the CPCB because of indoor activities like having traditional stoves (three stones) and using biomass fuel with inadequate kitchen ventilation (Gupta and Kumar, 2005).

According to the current study's results, the indoor air concentrations of $PM_{2.5}$ varied from 0.4mg/m^3 to 85mg/m^3 and median concentrations of $PM_{2.5}$ 1.18mg/m^3. The results suggest that using biomass fuel for indoor cooking has a significant influence on $PM_{2.5}$ concentrations and is consistent with the findings of Makhweli's (2003) study from Zimbabwe, and Parikh et al. (2000) study from India**.** The study also shows that when the house has an indoor kitchen that has no windows, or the windows are closed during cooking, the indoor $PM_{2.5}$ concentrations are twice (OR=2.31) as great as when there are windows open in the kitchen during cooking. In the current study, median indoor air concentrations of $PM_{2.5}$ exceeded the WHO's 8-hours guideline by 25 times when cooking indoors with biomass fuel (WHO AQG, 2000e) (set from 1.5 to 0.05mg/m^3). Rumchev et al. (2007) found concentrations of PM_{10} ranged from 0.23 to 7.33mg/m^3 and median concentrations were 2.52mg/m^3 in a Zimbabwean village. Parikh et al. (2000) study found concentrations of PM_{10} ranged from 0.5 to 2.0mg/m^3 in an Indian village, which were three times greater than the WHO air guideline value. However, the current study reported levels of 3.8mg/m^3 that were over 25 times higher. The study of Monkkonen et al. (2004), found median concentrations of $PM_{2.5}$ were more than 1.0 mg/m^3, which exceeded WHO guideline levels by 20 times for 8 hours guidelines for air quality.

Makhweli (2003), claims that kitchens with brick/stone walls are related to lower concentrations of PM_{10} (p=0.001) in the domestic air. Kitchen walls that are built of either thatch or mud have high concentrations of PM_{10} in the domestic air. The current study shows that kitchens with brick/stone walls and tile roofs are associated with reduced concentrations of $PM_{2.5}$ (p=0.033) because smoke and emissions can escape more easily outdoors through tile roofs. If a kitchen has mud walls, thatched roofs and floor of clay/mud, the indoor air has higher concentrations of $PM_{2.5}$ (p=0.014), which might be due to floor dampness and the thatched roof (made of coconut leaves). Thatched roofs are capable of retaining old and new smoke within the thatches (leaves) of the roof. However, no similar studies showed houses or kitchens' characteristics' risk factors influenced indoor concentrations of $PM_{2.5}$. Floors, such as cement, can lower the domestic air concentration of $PM_{2.5,}$ (p=0.014) because they are normally polished to prevent dust forming and clay/mud floors in houses/kitchens are covered with cowdung to keep clean and dry (see Table 5.8.2 (1). A study in Zimbabwe looked into some of the above-mentioned kitchen characteristics and found that similar roofs, walls and types of floors affected the indoor concentrations of respirable particles (Makhweli, 2003).

The Monkkonen et al. (2005) study reveals that cooking using biomass fuel with inadequate ventilation and malfunctioning or improperly-installed stoves can cause increased concentrations of $PM_{2.5.}$ The Parikh et al. (2000) study also shows that the concentrations of respirable particles were high during a two-hour cooking period with biomass fuel. A study from Nepal found that a much higher prevalence of all respiratory symptoms has been found among biomass fuel users, (shortness of breath and wheezing) (Joshi, 2008). The above-mentioned studies and Parikh et al.

(2000), Mandal and Mandal, (2002), Monkkonen et al. (2005) and Rumchev et al. (2007) argue that indoor air concentrations might be higher on account of house and kitchen characteristics and use the of biomass fuel. Studies by the National Institute for Occupational Safety and Health (NISOH) (1987) on the prevalence of respiratory symptoms in women who use biomass fuel, indicate the relative risk for cough (OR =3.2) is three times higher than for those who do not use biomass fuel, and shortness of breath (OR=4.6) is almost five times higher for mothers who use biomass fuel. While evidence is emerging that the incidence of tuberculosis is increasing amongst women/mothers who use biomass for cooking (Williams and Wilkins, 2009), the results of the current study in relation to tuberculosis are insignificant because of 170 women and mothers, only two mothers had tuberculosis. Mishra et al. (1999) reported an association between the use of biomass fuel and pulmonary tuberculosis had an odds ratio of 2.58 or almost three times more than compared to households that used cleaner fuel. However, some studies have evidence that shows an association between tuberculosis and biomass smoke exposure is extremely low (Saiyed, Patel and Gokani, 2001).

As far as house and kitchen characteristics associated with indoor air pollutant CO concentrations are concerned, the current study shows that CO concentrations were not significant in terms of mothers’ and children’s respiratory symptoms. Rumchev**,** Spickett and Makhweli (2005) study’s results show the median exposure level to CO is 25mg/m^3 for 4 hours. (NHMRC recommended that the guideline for CO levels should be 10.3mg/m^3 for 8 hours). The current study finds that lower concentrations of $PM_{2.5}$ were also found when windows were open (OR=0.14), (P=0.018). Collings et al. (1990) think that a poor ventilation rate could increase by two-fold the levels of exposure because of closed windows or a lack of proper ventilation in kitchens or houses. Higher concentrations of $PM_{2.5}$ are also due to poor kitchen ventilation. Strong/thick biomass cooking smoke results when the fuel is wet and/or green. Rinne et al. (2007) and Kurmi et al. (2008) studies also confirm that $PM_{2.5}$ higher concentrations are due to biomass’ strong/thick biomass cooking smoke and poor kitchen ventilation.

6.4.3 House and kitchen characteristics and activities associated with

respiratory symptoms in mothers

The current study finds when households have indoor kitchens and closed windows and cooking takes place with poor ventilation due to low roofs and walls and few windows, mothers were likely to have twice the rate of (OR=2.31) one of the upper respiratory symptoms; and mothers who cook with open windows and natural ventilation were seen to be have no upper respiratory symptoms (see Table: 5.8.4 (1)). A recent study found that women who lived in a house with few windows had a higher prevalence (84%) of respiratory symptoms, compared with those who had more windows in the kitchen (Rumchev, Spickett and Makhweli, 2005). The current study findings are similar to Parikh et al. (2000) and Monkkonen et al. (2004) studies' findings who state that higher concentrations of $PM_{2.5}$ could be explained by poor ventilation systems. Makhweli's (2003) study found concentrations depend on the type and size of kitchen and fuel used, and the material of the kitchen floor, be it clay, mud or cement.

When kitchen walls are built of either thatch or mud, mothers were three times more likely to have at least one upper respiratory symptom more than (OR=2.96) mothers who cooked in a kitchen built of stone or brick. Bruce et al. (1998) affirm a significant relationship between the types of kitchen floors and respiratory symptoms in women and mothers. A mud floor was significantly associated with chest illnesses (p=0.004), (Makhweli, 2003). The current study's results show that kitchens with mud floors are associated (p=0.041) with chest illnesses of mothers, a result similar to the study of Bruce et al. (1998) and Makhweli, (2003), who also found a significant association between the types of floor (mud) in the kitchens and respiratory symptoms in women and mothers. The current study finds the type of fuel and place of cooking influences respiratory symptoms in mothers. Ellegard (1996) shows that women who use biomass fuel had an incidence of more coughs than women who used LPG. Women cooking with biomass fuel have increased respiratory symptoms and a reduction in lung function compared to those using gas (Rehfuess, E 2006). The current study's results were borne out by Jaakkola and Jaakkola's (2006) research, which shows that an increase in respiratory symptoms and lung function impairment in children and mothers is related to biomass fuel smoke.

According to the current study, more mothers suffered from wheezing (79%) than other respiratory symptoms: the prevalence of cough was 43%, and chest pain was 36%. These prevalence rates are comparable with other studies such as Mandal and Mandal (2002) who found a prevalence of 63% for cough and 29% for chest colds/pain when households use biomass fuel for indoor cooking; and Rumchev (2001), reported that respiratory symptoms in women were coughs (79%) and chest colds (70%). In the current study, when the indoor T^{o}C was high, more mothers suffered from the following respiratory symptoms: 61 (71%) had wheezing, 47 (59%) mothers had a cough, 44 (55%) had chest pain and 23 (29%) mothers had shortness of breath. Higher temperatures may release some indoor pollutants into the air, which can increase concentrations of and can cause more respiratory problems. Physical, chemical and biological pollutants do not only determine indoor air quality, but are also affected by the parameters of indoor climate such as temperature and relative humidity. Temperature (TºC) and relative humidity (RH%) are very important parameters for enclosed environments such as homes and kitchens. Therefore, when the current study monitored indoor TºC and RH%, the results show that high TºC and RH% did not have any effect on mothers' respiratory symptoms. No significant factors were found for mothers' respiratory symptoms because of local cigar (bidi) indoor smoking ("passive smoking").

6.4.4 House and kitchen characteristics and activities associated with respiratory symptoms in children

In fact, children represent the largest sub-group of the population susceptible to the effects of air pollution, especially domestic air pollution (CDC, 2001). Among children, air pollutants are associated with increased acute respiratory illnesses, increased incidence of respiratory symptoms and infections, episodes of longer duration, and lowered lung function (Bates, 1995; Mishra, 2003). Honicky et al. (1985) argue that there is a significant association between respiratory symptoms and the time children spend in kitchens during meal preparation as babies are often attached to mothers' backs in slings. According to the current study, 56% of children reported having at least one respiratory symptom and the most commonly -

reported symptoms were chest congestion/wheezing (87%), runny nose (77%) and dry cough (47%). The results of Rumchev et al. (2007) study from Zimbabwe showed that 77% of children had at least one respiratory symptom and the most commonly-reported respiratory symptoms were chest congestion/wheezing (52%), dry cough (47%) and runny nose (40%). The current study establishes a significant relationship between respiratory symptoms in children and the location of the kitchen, types of walls, roof and floor and it was found outdoor cooking was protective against respiratory symptoms. The study of Rumchev et al. (2007) of a Zimbabwean village in Africa noted/observed similar outcomes.

In the current study, the odds ratio for at least one upper respiratory symptom for children living in indoor kitchens with traditional stoves and no flues was (OR=2.1) twice as high than children who lived in houses with separate kitchens with open windows and doors or open space/air stove cooking (see Appendix I, Figure 1a (iv) and Appendix L Photo 5c). Duflo et al. (2008) state that children who live in a house with a traditional stove without a flue had a higher incidence of respiratory symptoms, and Jayachandran (2006) claims that the use of traditional stoves without a flue had a higher incidence of respiratory symptoms and also states that 50% of children had experienced respiratory symptoms.

The current study found children in homes with outdoor cooking were less likely (OR=0.41) to have at least one upper respiratory symptom, compared to children who live in houses with indoor kitchens (OR=0.42), who had at least one lower respiratory symptom. When walls were built of thatch or mud, (OR=2.7) and the kitchen floor was made of clay or mud, children were almost three times more likely to have at least one lower respiratory symptom, compared to children who lived in houses with stone/brick walls and tile roofs and cement floors. Makhweli's (2003) study also indicates a similar outcome when the kitchen floor is made of clay or mud. In the current study, median levels of temperature and relative humidity in relation to respiratory symptoms (see Tables: 5.7.4 (1) & (2)) and indoor $T^{o}C$ and RH% did not have any significant impact on children's respiratory symptoms. There are no significant risk factors for children's respiratory symptoms from indoor smoking.

Rumchev’s (2001) study in Western Australia shows that high humidity significantly affects respiratory symptoms, such as wheezing, in young children, and indoor temperatures were significantly associated with hay fever because high temperatures can increase indoor air pollution concentrations. The current study found of the factors for respiratory symptoms, the domestic environment was associated with children’s respiratory symptoms. Spickett, Rumchev and Makhweli’s (2003) study also found that the domestic environment of Zimbabwe might be an important factor for women’s and children’s respiratory symptoms.

6.4.5 $PM_{2.5}$ and CO concentrations affecting respiratory symptoms in mothers

Costa and Brichus (2000) argue that air pollution might be significantly associated with respiratory symptoms. The current study also investigated mothers’ respiratory symptoms and their health effects due to indoor/domestic $PM_{2.5}$ and CO concentrations. The prevalence of having at least one respiratory symptom in mothers was 100%. As shown by Rumchev et al. (2007) in a Zimbabwean village study, the prevalence of respiratory symptoms was 94% for women. Other relevant research shows that when biomass is used for fuel, households’ $PM_{2.5}$ concentrations exceed the WHO guideline for $PM_{2.5}$ (Committee on the Medical Effects of Air Pollutants (COMEAP), (2006). According to the current study, $PM_{2.5}$ median concentrations were 4.80mg/m^3. Higher concentrations of $PM_{2.5,}$ were associated with more mothers suffering from the following symptoms: wheezing, cough, chest pain and shortness of breath. Although mothers with these symptoms were exposed to higher concentrations of $PM_{2.5}$ in the current study, no significant differences were established between mothers’ respiratory symptoms and CO concentrations. However, Rinne et al. (2007) claim that chronic CO exposure associated with biomass fuel use is thought to contribute to low birth weight and an increase in perinatal deaths. Kumar et al. (2008) also indicate that smoke from biomass combustion can produce CO, and measured levels of CO in the kitchen were in the range of 300-1,000ppm. Measured $PM_{2.5}$ concentrations in the current study are similar to other studies’ results such as Smith, (1998); Parikh et al. (2000).

6.4.6 $PM_{2.5}$ and CO concentrations affecting respiratory symptoms in children

The current study shows 56.5% of children had at least one respiratory symptom and this percentage includes 47% of children who coughed (p=0.035). Kumar et al. (2008) in their 'exposure-response study' found 44% of children presented with a history of respiratory symptoms and 38.3% had a cough, and their study concluded that indoor air pollution had an association with respiratory symptoms of children. The children with a cough lived in households where the median $PM_{2.5}$ concentration was $1.39mg/m^3$, and had the risk of having at least one upper respiratory symptom, compared to $0.72mg/m^3$ for children who did not cough. found no significant difference in concentrations of CO in children's respiratory symptoms. The current study shows that there is a significant relationship between the prevalence of asthma in children in relation to CO and more than one time (OR=1.19) with P=0.021. Rumchev's (2001) study found that high concentrations of CO are likely to be linked to asthma in children.

Children from poor households are exposed to high concentrations of $PM_{2.5}$ which is 25 times above the WHO's 8 hours guideline and 42 times above the Australian standard/guideline levels. Improving natural ventilation, increasing kitchen wall height, leaving doors and windows open during cooking, and shortening cooking time by using improved stoves with flues and children spending less time especially during cooking or spending more time outdoors can reduce indoor $PM_{2.5}$ concentrations. The RH% and local cigar (bidi) smoking ("passive smoking") were not found to have any significant impact on $PM_{2.5}$ and CO concentrations.

6.4.7 Observation on the SES of studied households in Tamil Nadu State of India

Most parents are employed as casual workers on building sites, in textile and similar industries, and factories. Most girls do domestic work and help mothers to collect firewood and only a few appear to attend school (see Appendix M, Photo n).

Personal observation during the field work indicated that children, especially girls, appear under-nourished (see Appendix M, Photo c) and boys look healthy and well-fed but boys are short for their age and seem to be suffering from stunted growth (see Appendix M, Photo j). Mothers look older than their age and are under-nourished (see Appendix M, Photos l & m). Girls are seen to be getting positive discriminatory treatment especially from their fathers and their grand mothers.

Mothers were seen to be suffering from hunger and poverty in greater numbers and to a greater degree than the rest of the household due their lower social and economical status in the society. In this community, poverty affects more mothers than other family members because there is a social and cultural expectation that mothers also have a greater responsibility to the family. Most of the households face increasing problems with poverty and the lack of access to basic needs such as education, health care, clean water, sanitation, nutrition and clean fuel for domestic use. They do not have private health insurance or easy access to public health care or financial institutions or co-operative societies (banks or building societies). Almost all households belong to scheduled castes (SCs)/dalit or untouchables. Therefore, they are socially disadvantaged people. Their houses and kitchens are in a very poor structural condition and some kitchens have no natural ventilation (see Appendix M, Photo m). Every household has free electricity, but use it for lighting and operating the TV. The majorities of adults, especially mothers, were employed and had incomes that were not sufficient for their basic needs such as food, clothing, schooling and health care but they are friendly and seem to be happy.

6.4.8 The influence of SES on the prevalence of respiratory symptoms in mothers

The women suffer from hunger and poverty in greater numbers and to a greater degree than men. This is also due to factors such as SES, levels of education, types of employment, lower family income, and cultural and religious practices (Kar et al., 1999). These risk factors may increase the susceptibility to respiratory symptoms in mothers (Mauskar, 2008). A study found a significant relationship between a household’s income and indoor air pollutant emissions, which can cause adverse respiratory symptoms in mothers (McLeod, 2000).

As revealed by the current study, the family's/mother's lower income appears to a effect the prevalence of respiratory symptoms. Working mothers with lower incomes who had a cough were 54 out of 139 compared to working mothers with higher incomes who numbered six out of 31 (see Table: 5.5.2). This finding was most significant (P=0.003) between lower and higher mothers' incomes. In addition, mothers from a low-income family are almost four times more likely to have coughs than mothers with high family incomes and the odds ratio was 4:1; and the same odds ratio was for chest pain, the difference was significant with a p-value equal to 0.001. Charafeddine and Boden (2008) argue that a family with a low income was found to be associated with poor health and indoor pollution, which is a risk factor for respiratory symptoms in mothers, while the study of Sanchez-Perez et al. (2001) also shows that one of the risk factors of high levels of poverty in Chiapas, Mexico, was associated with respiratory symptoms of diseases such as tuberculosis in poor women. According to the questionnaire survey of the current study, only two mothers had tuberculosis out of 170 mothers and women questioned.

In the current study, it was shown that mothers with lower incomes had shortness of breath (p=0.003), almost six times higher than mothers with higher incomes. Low-income family mothers were almost seven times more likely to have chest pain than higher family incomes' mothers were. Bronchitis was recorded occurring in mothers with low incomes compared to those with higher family incomes. Ekici et al. (2005) study showed households with a lower family income, who use biomass for cooking, suffered from chronic bronchitis or chronic airway diseases (CAD), obtained similar results. The current study results show that mothers had only one respiratory symptom (cough) that was significantly associated with households' SES and/or poverty levels in terms of whether they owned their own house/unit (p=0.048) because they lived in a temporary home which was badly constructed with inadequate basic facilities. This evidence has not been covered in any other study. The mothers who worked in a factory or on a building site were three times more likely (OR=3.03) to have lower respiratory symptoms, compared to mothers who stayed home. According to a study, mothers who worked in construction industries were mainly associated with bronchitis-like symptoms. The current study also shows a similar trend because most of the mothers worked as casual labourers in building industries under poor indoor/outdoor environments. Their incomes are very low and barely enable them to escape even from lower poverty levels.

Dasgupta et al. (2006) argue that overall, the poor and least-educated households have double the pollution concentrations of high-income households with higher-educated mothers. In addition, they found that the poor households with children and lower-educated mothers face pollution exposure four times greater than households with higher-educated mothers. The current study results revealed a trend similar to Dasgupta et al. (2006). Mothers or women who are exposed to indoor biomass smoke are three times more likely to suffer from chronic bronchitis or emphysema than those who use electricity, LPG or other clean fuels for cooking, boiling water and space-heating. Coal use cans double the risk of lung cancer, particularly among women (WHO, 2006b). However, the current study does not have results for either electricity or coal because the households did not use these fuels (WHO, 2006b).

6.4.9 The influence of SES on the prevalence of respiratory symptoms in children

Family income, living standards and family or parental employment and their educational levels measure the SES of children (Cohen et al., 2004). Low socio-economic factors can be basic elements of the causal pathways to poor health and disease, and these can affect early child development (WHO, 2008). Low childhood SES has been associated with adulthood sicknesses such as cardiovascular disease respiratory diseases, stroke, stomach cancer and lung cancer (Davey-Smith et al., 1998; Ayres, 2006). Children of low SES have been subjected to increased mortality from respiratory symptoms such as bronchitis and pneumonia and this social class also suffers from respiratory morbidity from lower respiratory tract infections (Tupasi et al., 1988; Jackson et al., 2004).

Low birth weight children of low SES households had a greater prevalence of lung function deficiency because of the role of nutrition on lung function than children with normal weight (Wheeler and Ben-Shlomo, 2005). Socio-economic conditions were significantly associated with four million children's deaths globally, between 1997 and 1999, because of respiratory infections (WHO, 2000d). Low SES conditions in childhood may be a risk factor for respiratory illnesses in adulthood. According to Osler et al. (2003), adults whose fathers had low SES and/or unknown social class at the time of birth, had twice the mortality rate than those whose fathers were high/middle class. Also, mortality from cardiovascular disease and violent deaths was significantly higher among men with fathers from the lower social classes or SES (Osler et al., 2003)). A close relationship between low SES in childhood led to decreased resistance to upper respiratory infections from rhinoviruses in adulthood (Cohen et al., 2004).

The current study evaluated children's SES, based on mothers' socio-economic position, rather than families'. The current study found that children whose mothers worked on building sites as casual labourers were more likely to have respiratory symptoms because the majority did not have an environmentally-friendly or permanent job, or good home environment. As far as family income in the current study was concerned, the number who coughed, 54 (39%) came from low-income families and only three (10%) (p=0.002) children came from high-income families. Therefore, lower family income appears to affect the prevalence of the respiratory symptoms of children's coughing and wheezing: 28 (20%), (P=0.002), but only one high-income (3.3%) child suffered from coughing and wheezing (p=0.024).

More respiratory symptoms were found in children of low SES, usually the hallmark of low socio-economic conditions (Mauskar, 2008). Children with allergies (78.9%) in the current study came from families where the mothers were employed as labourers and their children had respiratory symptoms such as coughing (p=0.001) and wheezing (p=0.002). The study of Rinne et al. (2005), found similar trends for a history of children's coughs (p=0.001). Lower parental education was associated with an increased prevalence of children's wheezing and dry cough (Gehring et al., 2006). The higher education of parents is a factor in the reduction of children's respiratory symptoms, especially those of chronic obstructive pulmonary diseases (COPD) (Hegewald and O' Crapo, 2007). The most (p=0.001) significant respiratory symptom of children from families who did not own house/unit or land was a cough: 56 (42.4%) as they usually live either in semi-open air or very badly constructed dwellings) No similar study, which directly connected to these factors, was found, but not owning land or home is one of the main factors for low SES. According to Cohen et al. (2004), children whose parents did not own their home during the children's childhood, would have the risk of having common colds when they are adults.

It was found that impaired lung function mostly affected children from poor households, which used biomass fuel for domestic purposes. (Rinnne et al., 2005). The study of Smith et al. (2000a) on indoor air pollution, due to biomass fuel, shows a significant increase in risk exposure to young children, compared with those living in households using clean fuel. The current study found more households (83%) use biomass fuel because of their low SES; therefore, children from such families are susceptible to the adverse health effects of domestic air pollution, particularly respiratory symptoms, due to noxious biomass smoke (Dockery et al., 2005). As evidenced by the current study, because of low SES, these households live in poor indoor and outdoor polluted environments. The correlation between low SES and environmental pollution was also found in Gupta & Kumar (2007), study. As shown by Table 5.5.5 (3), there are no significant (p value) relationships between children's respiratory symptoms (cough, wheezing, asthma, runny nose and tonsillectomy) and mothers' level of education.

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

Globally, in the modern environment, air, both indoors and outdoors, is vastly different from that of a few generations ago because of increasing urbanization, industrialization and the widening poverty gap among the poor in developing countries. The indoor environment may contribute more pollutants than any other especially domestic, as homes have several sources of hazard that contribute to poor domestic air pollution concentrations. The current study and other studies' results show that homes have serious indoor air pollution. There are many risk factors associated with domestic/indoor pollution such as domestic air pollutants, the indoor and outdoor environment and households' activities, characteristics of the home and/or kitchens and households' SES and/or poverty levels. The home is the most important indoor environment for mothers and young children. Children need special protection because they are more vulnerable to the effects of poor environment, especially domestic, as they spend more time indoors than outdoors. According to the current study's results, one of the risk factors is when households use biomass fuel for cooking and where young children are indoors for longer periods per day than adults. Young mothers and grandmothers often have their babies and infants with them while they cook indoors (see Appendix L, Photos 2b, 3 & 4a).

In India, there is serious inequality in society due to the caste system, economical values (extremely rich or extremely poor) where the majorities affected are the poor, minority groups such as tribal groups, women/mothers and lowest caste households. According to the current study, households with low SES (important three main variable of SES are income, education and occupation and the fourth variable is wealth when determining SES) plays a very important role in the health of poor households' mothers and children, beside other factors such as genetic factors. Improving family incomes will also give a chance to households to switch to clean fuel, such as LPG and/or electricity (see Appendix H, Figures 1a & 1b). The current study found that changing to electricity, except for lighting is too expensive for these poor households because of their very low income. The Government of India phased-out the subsidy for fossil fuels in 2002, and as a result, the price of LPG and electricity rose, and now poor households cannot afford clean fuel (energy access improvement could have a significant impact on socio-economic status, including health). The current study found that 73% of households still use biomass fuel, 17% use only LPG and the rest of the households (10%) use kerosene or diesel for cooking, the majority of households living on less than $1 US a day.

Switching to a clean fuel and improving the domestic environment, such as the structure and characteristics of homes, kitchens, and households' activities, will also help to reduce indoor concentrations of $PM_{2.5}$ and exposure levels of poor domestic air quality. Although reducing concentrations of carbon monoxide (CO) was a consideration during the current study, according to its statistical analysis results, no significant difference was found in concentrations of CO in the domestic environment and respiratory symptoms of mothers and children. However, it was found that a lower SES might have contributed to the high prevalence of respiratory symptoms in mothers and children.

For many years, the global community has been aware of research and policy development related to the social context of mother and child health, mainly in developing countries. There are four major elements for reducing health inequality:

improve mothers' educational level, daily living conditions, improve the distribution of power, money (income), and resources. The use of cleaner fuel, cultural specificity, and environmentally-friendly housing improvements, with community participation, are important means of reducing the prevalence of respiratory symptoms in mothers and children. The reduction of risk associated with domestic air pollution for economically and socially-disadvantaged households should be a high priority. To solve this issue, a greater amount of financial assistance is needed from planners and providers.

7.2 Recommendations

Past experience has shown that appropriate participation is needed for both setting priorities and implementing the recommendations. Most important, a household's multilateral agencies should all participate, such as the WHO, the World Bank, the Asian Development Bank, national and local governments, civil society, the private sector, NGOs and research institutions. Mothers need to become active participants in this program and should also make decisions about type of fuel, stoves, kitchens and their house structures and children's health. Reducing domestic air pollution is a difficult task in India, and elsewhere in developing countries, because of the multi-faceted nature of the problem. This includes low SES of households, their habits and customs, behaviour, physiological and policy issues. The current study recommendations are detailed below. To reduce the concentrations of domestic air pollution, improvements should be made to house or kitchen structures using good building materials and high-roofed kitchens and keeping the location of the stove within the partition walls. Improvement to the natural ventilation of kitchens by keeping all windows and doors open during cooking will also assist in reducing concentrations of indoor air pollutants and exposure levels.

Replacing the traditional three-stone stoves with an improved version that can reduce emissions and shorten cooking time and the installation of a flue can also reduce smoke accumulation indoors. Having the stove located not less than waist height would further reduce exposure to stove emissions. Maintaining a lower level of temperature and relative humidity can help to reduce the impact of indoor air pollution.

Domestic air pollution exposure can be halved by ensuring children spend about 3-to-6 hours per day outdoors during peak cooking periods. Advice should be given to mothers to stop carrying their babies and infants on their backs during cooking. Mothers should be advised to stop using biomass fuel especially during indoor cooking and be persuaded to use clean fuels such as LPG and/or cooking outdoors in either a separate kitchen or on an open air stove to further reduce exposure levels.

A program should be able to create time and opportunities for mothers to engage in income-generating activities and to alleviate time-consuming labour. Short-term help such as free or subsidised LPG to poor households will give health benefits. For longer-term benefits, low SES households could work with local (State) and union (Indian) governments to improve the reliability of LPG supply systems and develop joint projects with them and NGOs communities could promote LPG use in poor households. Currently running is Tamil Nadu’s Empowerment and Poverty Reduction Project, which seeks to improve the rural poor’s livelihoods and health through social, economic and democratic empowerment with the World Bank. It should be given more encouragement by local and international financial organizations.

1. How to reduce concentrations of households’ pollutants

Potential interventions for reducing concentrations of domestic air pollution are firstly: improve house or kitchen structures using good building materials (brick walls, cement floors and tile roofs if possible) more windows and doors, install/construct larger floor areas and high-roofed kitchens, as these help stop smoke accumulation. Secondly, improve the natural ventilation of kitchens during cooking and keep all windows and doors open. Thirdly, if cooking is done inside the house, keep the location of the stove within partition walls and all windows and doors open, particularly during cooking. These changes can reduce concentrations of indoor air pollutants.

2. How to reduce households' emissions

Replacing traditional three-stone stoves with an improved version that can reduce emissions, even with biomass fuel, 12 times shorter cooking than traditional stoves, can also shorten cooking time (Oanh, et al., 2005). Furthermore, installation of a flue or chimney can also improve and stop smoke accumulation. Switching to LPG and making the height of stove location not less than waist height would further improve the benefits of the stove emissions (smoke) accumulating in the indoor cooking area. Maintaining a lower level of humidity can help to reduce concentrations of $PM_{2.5}$ by improving ventilation of the house and/or kitchen where cooking is done (see Appendix l, Photo 4a). These measures should prove affordable and should be cost effective in the long term, even for very poor households.

3. How to reduce exposure of households

Reducing domestic exposure levels is one of the important steps of intervention that can reduce the adverse affects of domestic air pollutants in mothers and children. Domestic air pollution exposure can be halved by adopting three simple measures with a community awareness program for households, particularly involving mothers, for health and behaviour changes. Firstly, ensure children spend about 3-to-6 hours per day outdoors during peak cooking periods. Keeping young children outdoors may be difficult, but the potential benefits are great. Secondly, advice should be given to mothers to stop carrying their babies and infants on their backs, especially during cooking. Thirdly, mothers should also be made aware of the health hazards associated with cooking smoke and how to reduce poor indoor pollution when using biomass fuel for domestic cooking. In addition, households should be persuaded to use clean fuel or cook outdoors in either a separate kitchen or open stove, which will further reduce exposure levels (see Appendix I, Figure 1a & Appendix L, Photo 5c).

4. How to improve households' SES and/or poverty levels

Reducing economic and social inequality can lead to greater social cohesiveness, better standards of health and social status (the fourth variable is wealth when determining SES and/or poverty levels) and economic conditions. Low SES may cause greater susceptibility to disease through use of polluting fuel for cooking and other effects associated with poverty such as malnutrition, access to health care, better housing and children and adult (mothers') education. The main goal should be sustainable development and poverty reduction that will enable people eventually to switch to clean fuel (see Appendix H, Figure 1a & 1b). In India, corruption exists at all levels, and households which are most affected are poor households. Removing corruption can be a major means of improvement, including poverty alleviation and thereby reducing indoor air pollution and improving households' health, mainly mothers' and children's respiratory health (Wolff., Schroeder & Young, 2001).

Poor households should be able to create time and opportunities for mothers to engage in income-generating activities and to alleviate time-consuming labour and adverse impacts on their own and their children's health. Improvement of households' low SES and/or poverty levels can be achieved though households' increased income, higher education for adults particularly for mothers and children and health education for mothers. Better employment or occupation status will enable them to switch to clean fuel for domestic use and good health. If households' low SES improves, they can move up the energy ladder from biomass fuel to cleaner fuel such as LPG or natural gas (see Appendix H, Figures 1a & 1b). Short-term help such as free or subsidised LPG to poor households will give health benefits. Finally, although the caste system was abolished in the early' 50s, it is still widely practised in India, including Tamil Nadu, due to cultural and religious practices. Finding a solution to remove the widely-practised caste system is beyond the scope of the current study. The Indian government has already taken measures to improve their low SES by allocating more university places and government jobs for lower caste families' children and young adults.

5. Recommendations for further study

The current study concludes that these recommendations be taken into account to improve households' SES and/or poverty levels that are the main risk factors for adverse health effects of respiratory symptoms in mothers and children in Tamil Nadu, South India, and also elsewhere in India. The four colonies in Tamil Nadu may be representative of all other colonies in Tamil Nadu but still the households' environmental problems could be different and home-specific from other States in India. The current study only covered the dry season and because of time and resource limitations, data collection was conducted only in the summer/dry season. Therefore, a future study is recommended for domestic air quality and health effects on mothers and children during the wet season in Tamil Nadu, in India and also further research on social determinants on poor households, especially mothers' and children's health.

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APPENDICES

Appendix A

School of Public Health

QUESTIONNAIRE

FORM OF CONSENT

____

Given/first name Surname

I have read the information explaining the study entitled “Indoor air quality, social and economical factors and respiratory symptoms among mothers and children from Tamil Nadu State in India”. I agree to participate in the study and I understand that I can withdraw from the study at any time. I agree that research data gathered from the results of the study may be published, if names are not used.

Your signature__________________________

Date ____

Researcher___________________________________

Date _________________________

Appendix B

INFORMATION SHEET FOR PARENTS

Dear Parent/Guardian

We are conducting a study entitled “Indoor air quality, social and economical factors, and respiratory symptoms among mothers and children from Tamil Nadu State in India” from the School of Public Health, Curtin University of Technology, Western Australia. There is strong evidence of links between respiratory symptoms and exposure to indoor air pollutants. The present study will investigate particles 2.5 micrometers in diameter ($PM_{2.5}$) and carbon monoxide gas (CO). The major sources of these pollutants are the types of fuel used for cooking and/or heating in Tamil Nadu.

The current study will consist of two stages:

The first part will involve a questionnaire interview related to mothers’ and children’s health and as well as house types. The second part will involve indoor monitoring for $PM_{2.5,}$ CO, temperature and relative humidity during the dry seasons where cooking is taking place. A researcher will contact you to make a visit in your home at a time convenient for you. We would appreciate you taking part in both parts of the current study and invite you to sign the consent form. The current study is voluntary and you are free to withdraw at any time. You will not be identified.

The information you provide will be kept private and will only be used for research purposes. All these procedures will involve no cost to you and the results of the current study will be made available to all who take part. Your participation in the current study will be greatly appreciated and should you have any questions or concerns about the current, feel free to contact: Mr. Morgan D Kandiah, Mob: 0419 963 043.

Thank you,

Morgan Dharmaratnam Kandiah

(DrPH Researcher)

School of Public Health, Curtin University of Technology, Western Australia.

Appendix C

QUESTIONNAIRE

SECTION A:

IDENTIFICATION NUMBER (house no) __________

District name & Number: ____

Date: _______________

MOTHERS' HEALTH QUESTIONNAIRE

(This section will ask you mainly about you and your health environment. Please be assured that your answers will remain strictly confidential.)

1. Age in years______________________________
2. Place of birth: _____________________________
3. What is your marital status?
   1. Single
   2. Married
   3. Widowed

4. What is your highest qualification?

Year 10, __, Year 12, __ TAFE __ University __

5. What is the highest qualification of your spouse?

Year 10, __, Year 12, __ TAFE __ University __

6. What is your occupation? ____

7. What is your spouse's occupation? ______________________________________

8. Household/Family income Low ______ High ______

COUGH (Mother's respiratory symptoms)

9A. Do you usually have a cough? 1 Yes 2 No

If no, go to question 10A

IF YES TO 9A, ANSWER THE FOLLOWING:

9B. Do you usually cough like this on most days for the last months or more during the year? 1 Yes 2.No

9C. For how many years have you had this cough?

Number of years __________________________

WHEEZING

10A. Do you usually have wheezing? 1. Yes 2. No

IF no go TO 11A

10B Most days or nights? l. Yes 2.No

10C. Have you ever required medicine or treatment? for the attack(s)? 1. Yes 2. No

BREATHLESSNESS

11A. Are you troubled by shortness of breath? l. Yes 2. No

12A. Have you ever had bronchitis? 1.Yes 2. No

13A. Have you ever had pneumonia? l. Yes 2.No

14A. Have you ever had hay fever? 1. Yes 2.No

15A. Have you ever had emphysema? 1. Yes 2.No

16A. Have you had or ever had tuberculosis? 1. Yes 2.No

OCCUPATIONAL HISTORY

17A. Have you worked in the last 5 years in any poor indoor or outdoor (dusty or smelly) environment? 1. Yes 2.No

TOBACCO SMOKING

18A. Does any member of this household smoke? 1. Yes 2. No

IF no go to 18B

What types of tobacco do you smoke?

Cigarettes 1. Yes 2. No
Cigars (local) 1. Yes 2. No

18B. Do you have visitors that smokes? 1. Yes 2. No

18C. Do they usually smoke indoors? 1. Yes 2. No

FAMILY HEALTH HISTORY

19A. Do you have a family history of type of illness or chronic lung condition such as

Mother:	1.YES	2. NO	3. DON'T KNOW
19B. Does mother have lung cancer?	______	______	____________

19C.Other chest conditions____

Father:	1.YES	2. NO	3. DON'T KNOW
19D. Chronic bronchitis?	______	______	____________
19E. Emphysema?	______	______	____________
19F. Asthma?	______	______	____________

CHILDREN'S HEALTH QUESTIONS

(This questionnaire will ask you mainly about your child's health history and status. Be assured that your answers will remain strictly confidential.)

20. In the last 12 months, has your child usually seemed congested in the chest or coughed up phlegm when he or she did not have colds? 1. Yes 2. No

If no go to question 21

20. For how many years has this happened? ______________

21. In the last 12 months has your child had wheezing or whistling ?

1. Yes 2. No

22. Has your child ever been diagnosed with asthma? 1. Yes 2. No

If no, go to Question 24

23. In the last 12 months, has your child had any medication for asthma? 1.Yes. 2. No

24. In the last 12 months, has your child had a problem of sneezing or runny nose? 1.Yes. 2. No

25. Has your child ever had hay fever? 1.Yes 2. No

26. Has your child ever had an itchy rash? l. Yes 2.No

27. Has your child ever had eczema? 1.Yes 2.No

28. Has your child ever had tonsillectomy? 1.Yes 2.No

SECTION B:

HOUSING/DWELLING QUESTIONNAIRE

(The questions in this section relate to your home environment. Please be assured that your answers will remain strictly confidential)

29. How many rooms are there in your home? ________

30. How many people live in this household? __________

31. How many children younger than 15years live in this household? __________

HOUSING CONSTRUCTION CHARACTERISTICS

Questions 32 to 36 interviewer to observe and measure

32. Where is normal cooking done?

1 inside
2 outside

33. What type of material is the kitchen floor made from?

1 clay and mud
2 cement

3 other _______

34. What type of roof (material of construction?)

does the kitchen level?

1 thatch
2 iron sheets
3 asbestos
4 other________

35. What type of wall (material of construction) is the kitchen made of?

1 thatch
2 wood
3 mud & wood
4 stone or brick
other_______

36. Number of windows in the room in which cooking takes place ______

DOMESTIC ACTIVITIES

37. Where do you do your cooking?

1 kitchen/house
2 shed outside
3 open outside
4 other_______

IF INSIDE;

38. Do you normally open doors during cooking? 1.Yes 2. No

39 Do you normally open windows during cooking? 1. Yes 2. No

(assess good or bad ventilation)

40. Is there any poor outdoor air influence during cooking? 1. Yes 2. No

41. How many people are normally present in the kitchen when cooking is being done? ___________

42. Who is normally present during cooking times in the kitchen?

1 mother
2 mother & children less than 5yrs
3 mother & children
4 whole families
5 other_________

43. What fuel is usually used for cooking?

1. firewood (biomass fuels)
2. LPG
3. other _________

44. What source of lighting do you use?

1. lanterns
2. candles
3. cooking fire
4. gas lamp
5. electricity

6. other____________

45. What type of stove is used for cooking (in terms of combustion chamber)?

1 open combustion
2 partly open combustion
3 enclosed chamber with no flue
4 enclosed chamber with a flue
5 other ____________________

46. How much time on average does cooking take per day? _____________ (hrs)

47. How much time do you spend indoors on an average day? ___________ (hrs)

SECTION C

HOUSEHOLD POVERTY INDICATORS

48 Do you own the land?	1.Yes	2 No
49 Do you own house/unit?	1. Yes	2 No
50 Do you receive poor relief assistance?	1 Yes	2 No

(Extra addition)

51 Number of children >6 <10 years old

52 Number of children >11 <15 years old

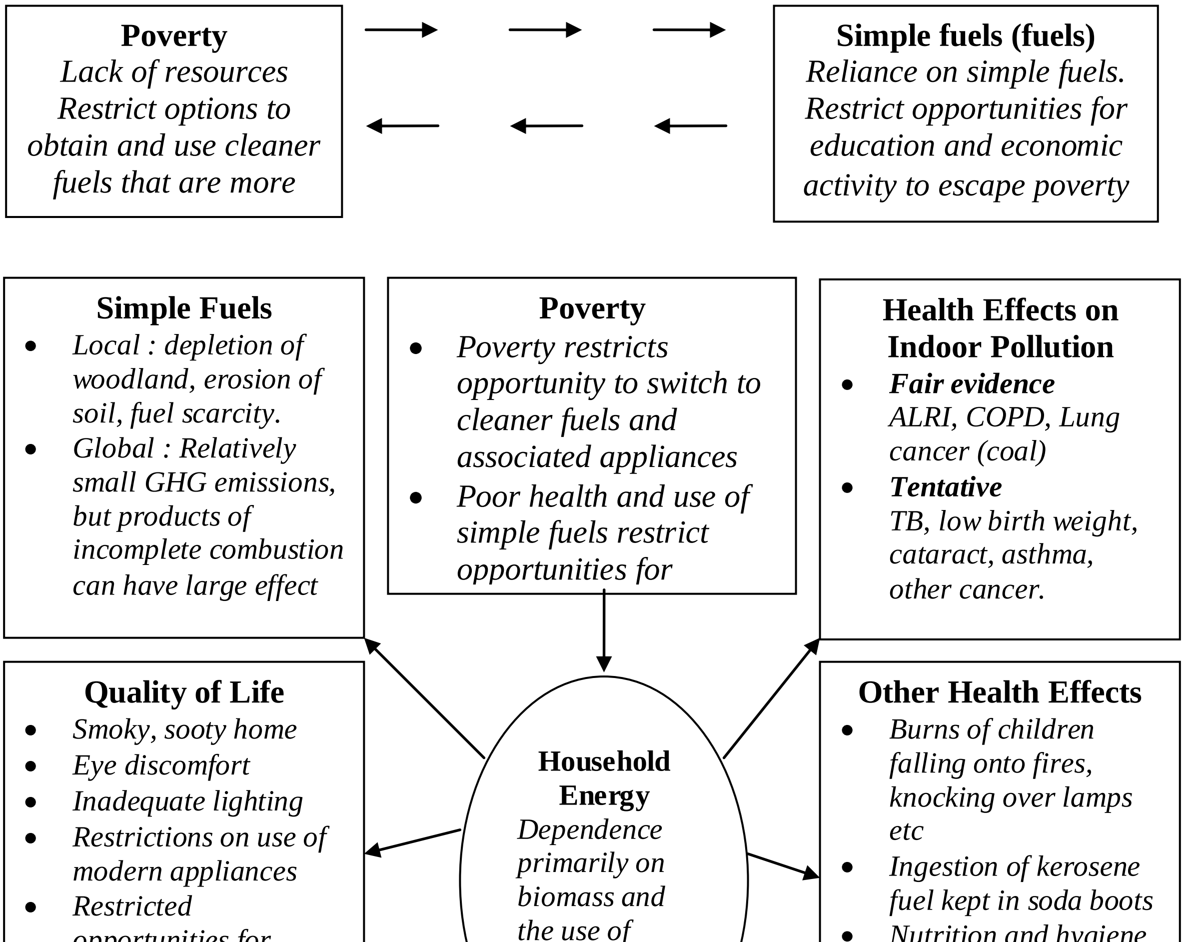
Thank you very much for your participation

APPENDICES AND LIST OF FIGURES
Appendix D

Figure 1 Summary of health and development issues associated with the use of household energy in developing countries (WHO, 2000d, pp.14).

Poverty makes it worse

The diagram of household energy is inter-related to poverty, health effects of indoor pollution, and other health effects, simple fuels, quality of life and gender issues. This also shows, in the case of socio-economic status, IAQ is a greater problem.



Poverty
Lack of resources
Restrict options to obtain and use cleaner fuels that are more

Simple fuels (fuels)
Reliance on simple fuels.
Restrict opportunities for education and economic activity to escape poverty

Simple Fuels
- *Local : depletion of woodland, erosion of soil, fuel scarcity.*
- *Global : Relatively small GHG emissions, but products of incomplete combustion can have large effect*

Poverty
- *Poverty restricts opportunity to switch to cleaner fuels and associated appliances*
- *Poor health and use of simple fuels restrict opportunities for*

Health Effects on Indoor Pollution
- ***Fair evidence***
  ALRI, COPD, Lung cancer (coal)
- ***Tentative***
  TB, low birth weight, cataract, asthma, other cancer.

Quality of Life
- *Smoky, sooty home*
- *Eye discomfort*
- *Inadequate lighting*
- *Restrictions on use of modern appliances*
- *Restricted opportunities for*

Household Energy
Dependence primarily on biomass and the use of

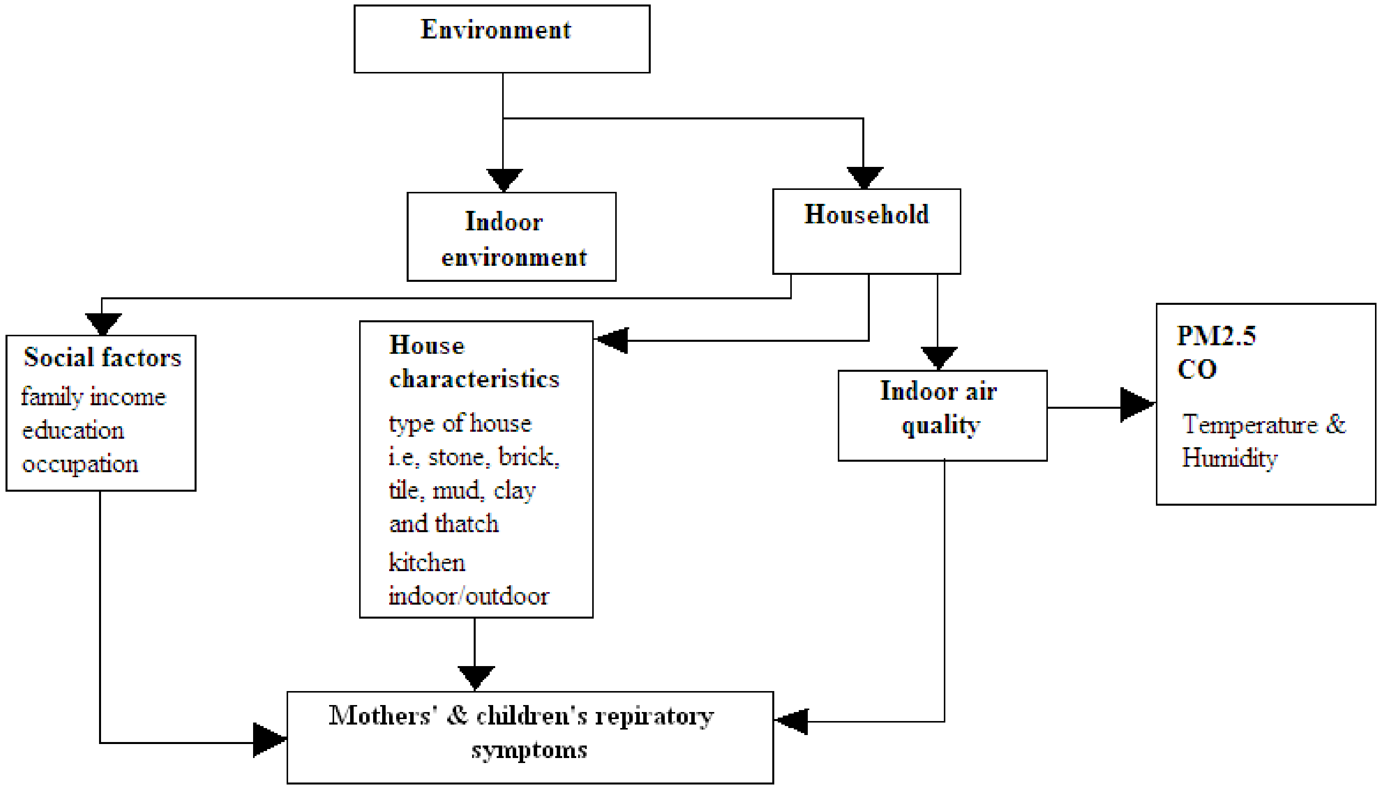
Other Health Effects
- *Burns of children falling onto fires, knocking over lamps etc*
- *Ingestion of kerosene fuel kept in soda boots*
- *Nutrition and hygiene*

Gender Issues

- *Mothers have greatest exposure to IAP*
- *Opportunity cost of time collecting fuel.*
- *Injuries collecting and carrying fuel.*
- *Limited decision making power in homes for new fuel and appliances*

Appe

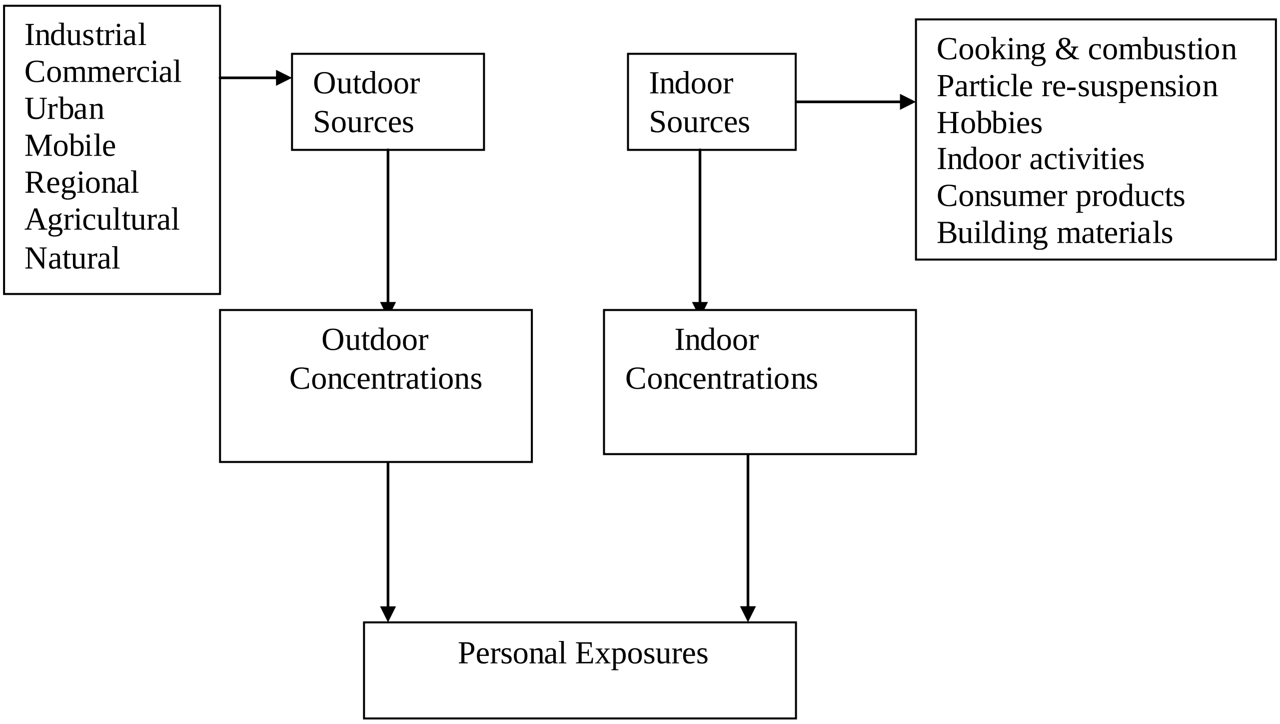
Figure 1 Conceptual framework of the current study



Indoor air quality, respiratory symptoms among mothers, children, and association with housing, environmental and social-economic factors in Tamil Nadu in South India.

Appendix F

Figure 1 Sources and factors influencing indoor, outdoor and personal Exposure to air pollutants. (adapted from National Research Council (NRC) & committee on Advances in Assessing Human Exposure to Airborne Pollutants 1991, pp.15).



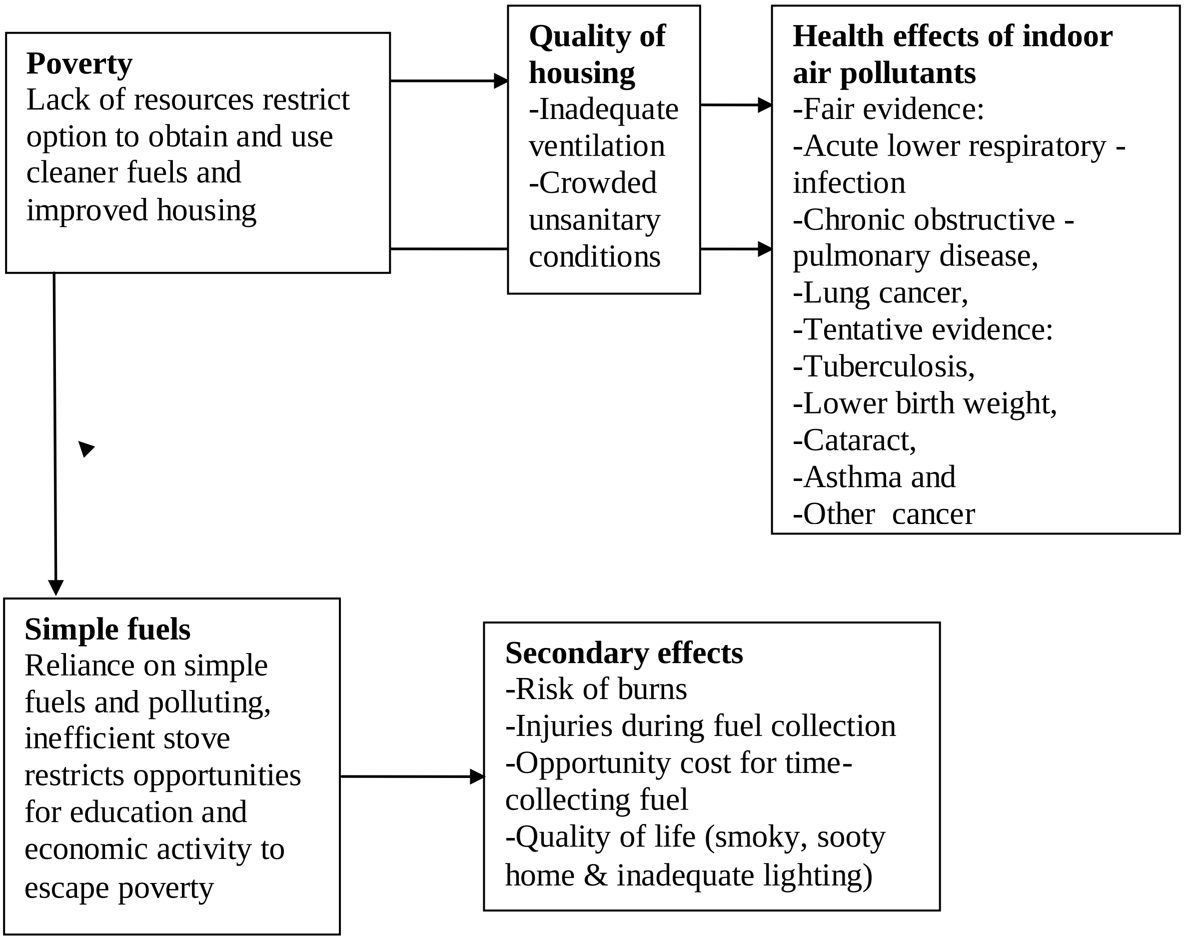
Exposure Assessment

Exposure assessment begins with identification of key sources of selected pollutants and their emission rates into the air.

Appendix G

Figure 1 Air quality and health in relation to poverty, housing and fuels

(adapted from WHO Regional Office for Europe (WHO, 2005a, pp.13).



Appendix H

Figure 1a Household energy ladder typical in South Asia

(adapted from Smith, Mehta & Maeusezahl-Feuz, (2004, pp. 588).

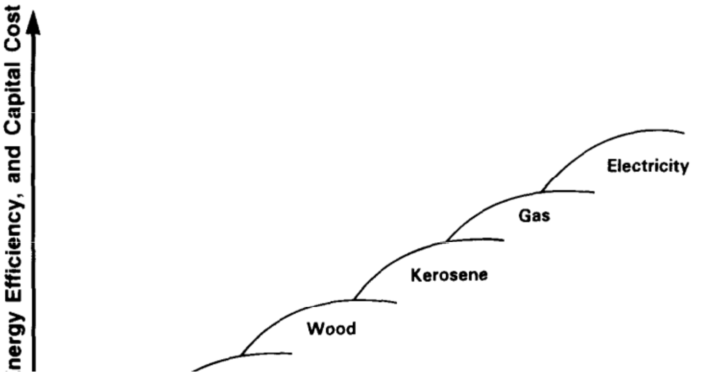
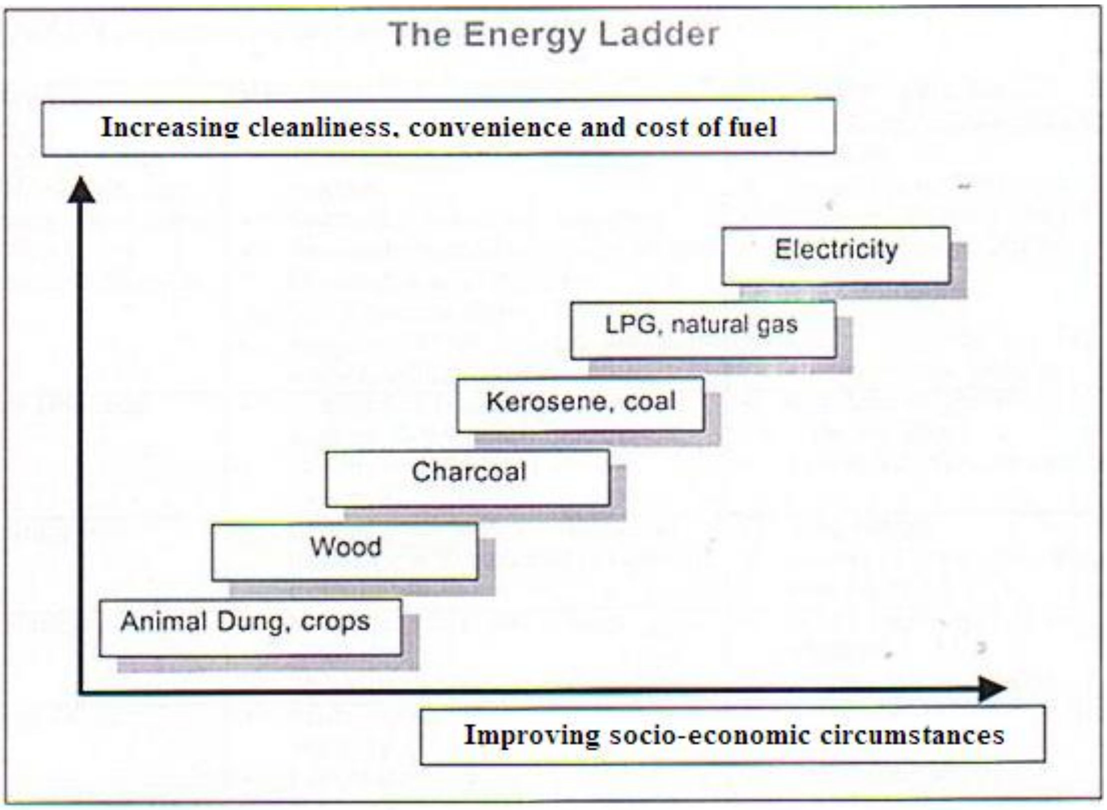


Figure 1b In practice, most households use a combination of fuels, and this mix shifts as prosperity increases (adapter from Smith et al., 1994, p. 10)



Appendix I

Figure 1a The floor layout of different locations of cooking stoves (three stones) in Tamil Nadu households (adapted from Parikh et al., 2000, pp. 953).

(i) Indoor kitchen with no partition

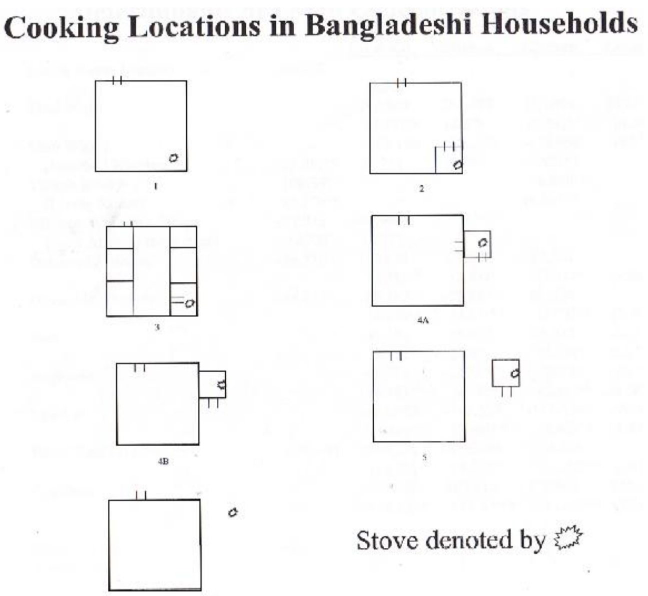
(ii) Separate kitchen inside house

(iii) Separate kitchen outside house

(iv) Outdoor kitchen

Appendix I

Figure 1b (adapted from 1998 Dasgupta et al., 2004, pp.11)



Appendix I

Figure 1c Components of poverty and their links

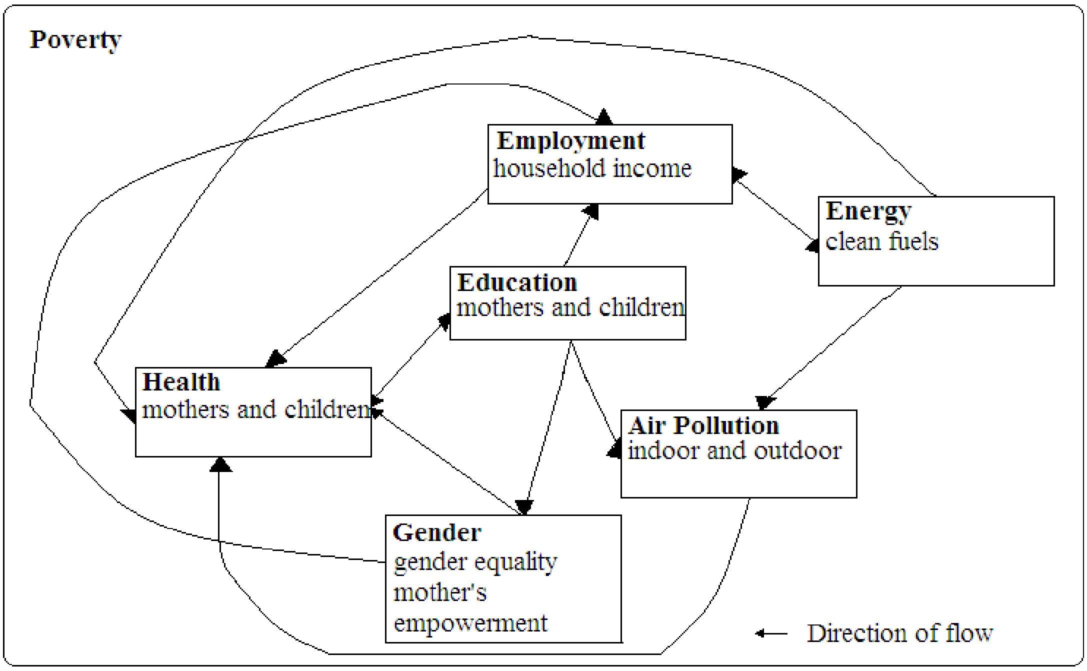
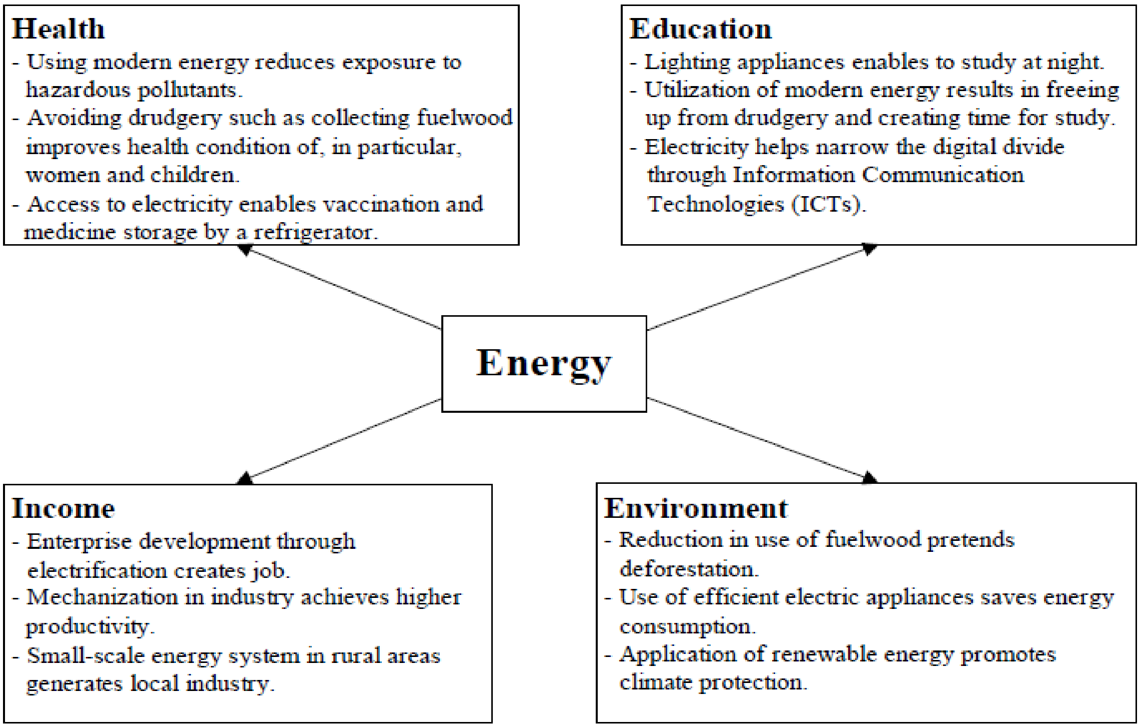


Figure 1c illustrates one of the current study's aims: the relation between energy and poverty reduction. According to this figure, most fundamental components of development are socio-economic aspects, education, health, and gender. These components are intricately connected with each other, and show that energy potential has a greater influence on these development components (Kanagawa and Nakata, 2004).

Appendix I

Figure 1d The influence of energy on the other components



Health
- Using modern energy reduces exposure to hazardous pollutants.
- Avoiding drudgery such as collecting fuelwood improves health condition of, in particular, women and children.
- Access to electricity enables vaccination and medicine storage by a refrigerator.

Education
- Lighting appliances enables to study at night.
- Utilization of modern energy results in freeing up from drudgery and creating time for study.
- Electricity helps narrow the digital divide through Information Communication Technologies (ICTs).

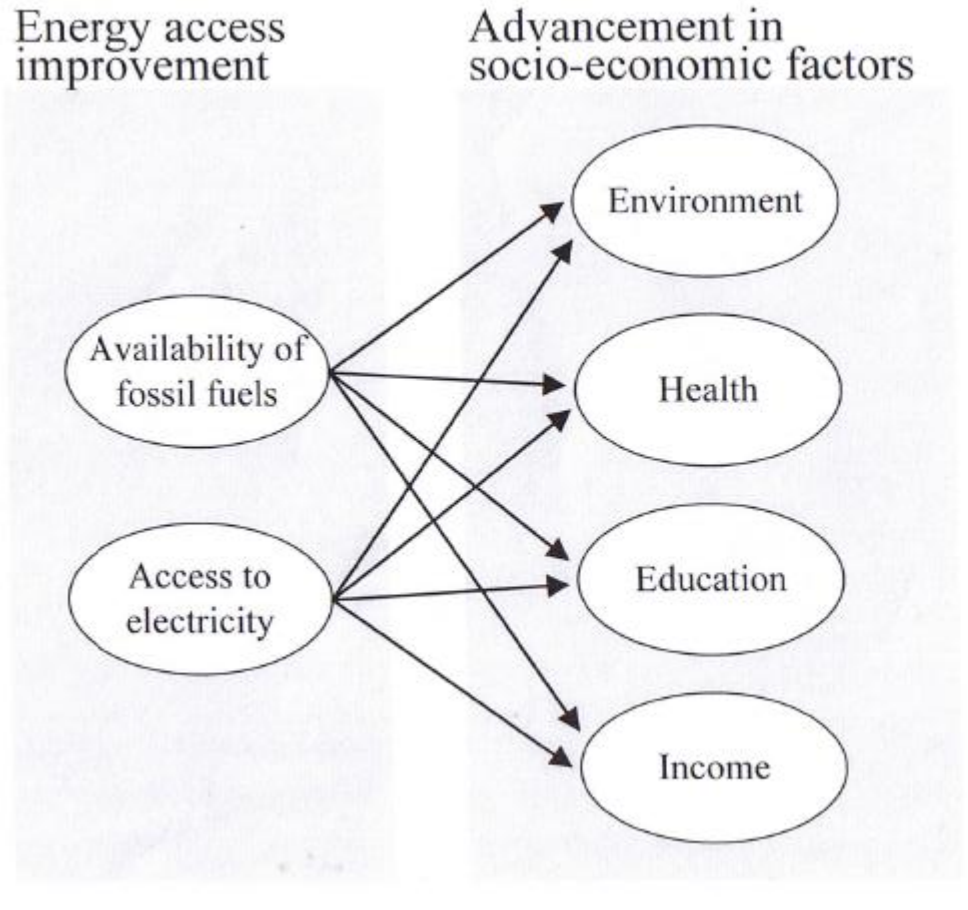
Income
- Enterprise development through electrification creates job.
- Mechanization in industry achieves higher productivity.
- Small-scale energy system in rural areas generates local industry.

Environment
- Reduction in use of fuelwood pretends deforestation.
- Use of efficient electric appliances saves energy consumption.
- Application of renewable energy promotes climate protection.

"Energy is a fundamental requirement for development and one of the most influential components of poverty reduction in developing countries" (Kanagawa & Nakata, 2004, p.15 & p.28).

Appendix J

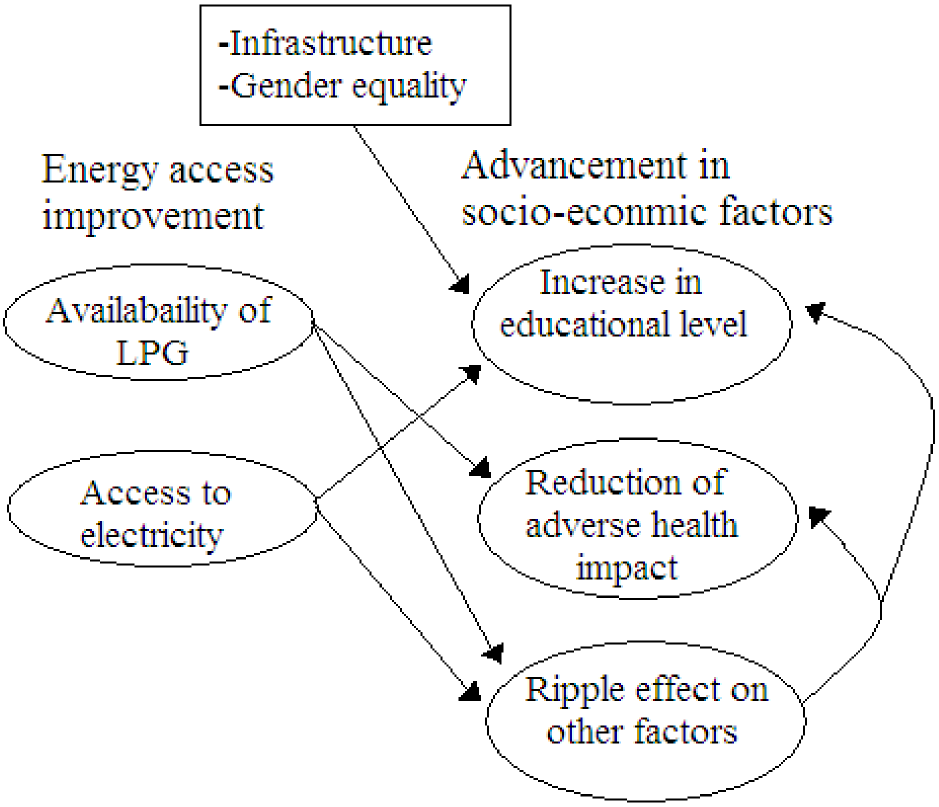
Figure 1 Energy access and poverty alleviation (Kanagawa & Nakata, 2006b, p.3).



Poverty alleviation depends not only on economic aspects such as income but also on social aspects such as education and health. Improvement of energy access can contribute to improved SES and/or poverty levels or for poverty reduction.

Appendix K

Figure 1a Socio-economic impacts of energy poverty alleviation in rural areas of developing countries (adapted from Kanagawa & Nakata, 2006b, p. 9)

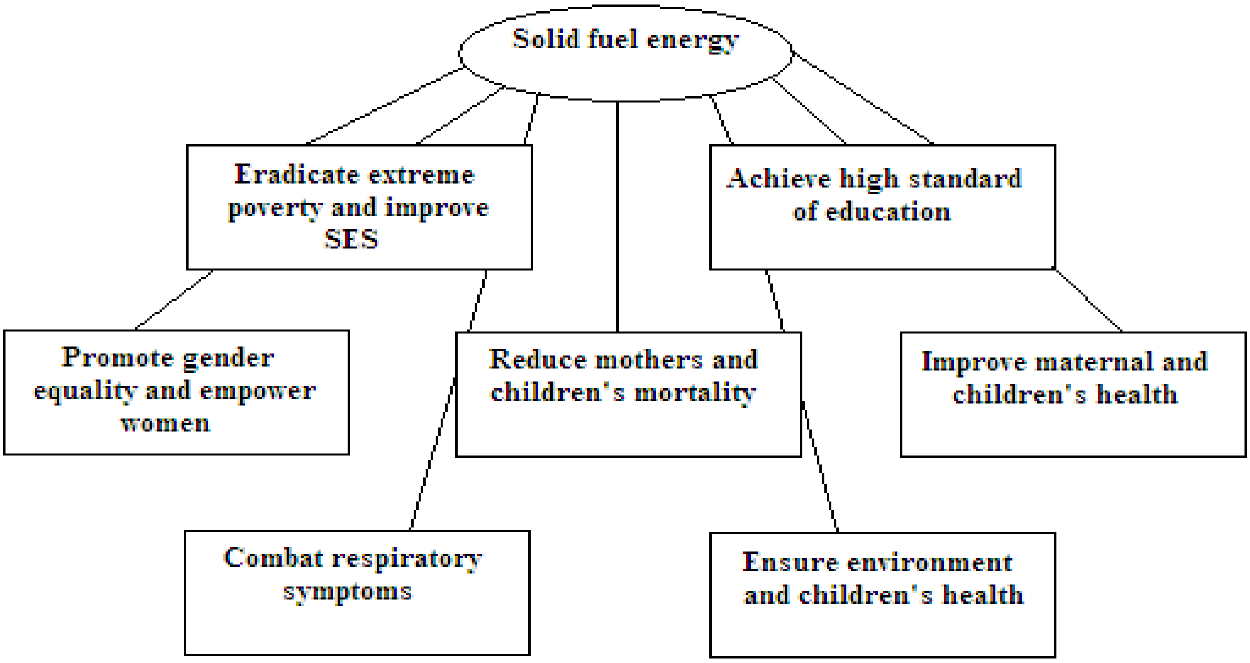


Improving socio-economic factors (SEFs) such as educational standards, income level, gender (women's) equity, infrastructure, capacity of supply, government policy and international cooperation can improve availability of LPG and access to cleaner fuels, such as electricity, which can improve SES and/or poverty levels to reduce adverse health of poor households.

Appendix K

Figure 1b Development goals through providing solid fuel energy

(adapted from WHO, 2005b, p.8).



Providing access to modern or clean fuels mothers and children will get higher exposure to air pollution if clean energy sources are not used means mothers can have extra time to pursue educational, economic, their health and children’s matters and other opportunities, which can empower them and promote gender equality and improve mothers’ and children’s respiratory symptoms.

APPENDICES AND LIST OF PHOTOGRAPHS

Appendix L

Photos 1a & 1b Young girls carrying cooking fuels (cow dung and tree branches), (Mahanama, 2004).

(a) **(b)**

Photo 1c Mothers carrying firewood for cooking and other domestic uses (WHO, 2005b)

(c)

Cooking or being cooked:

Photo 2a Wood used for cooking in a closed kitchen (Mahanama, 2004).

Photo 2b A child with her grandmother in a Sri Lankan household (Mahanama, 2004).

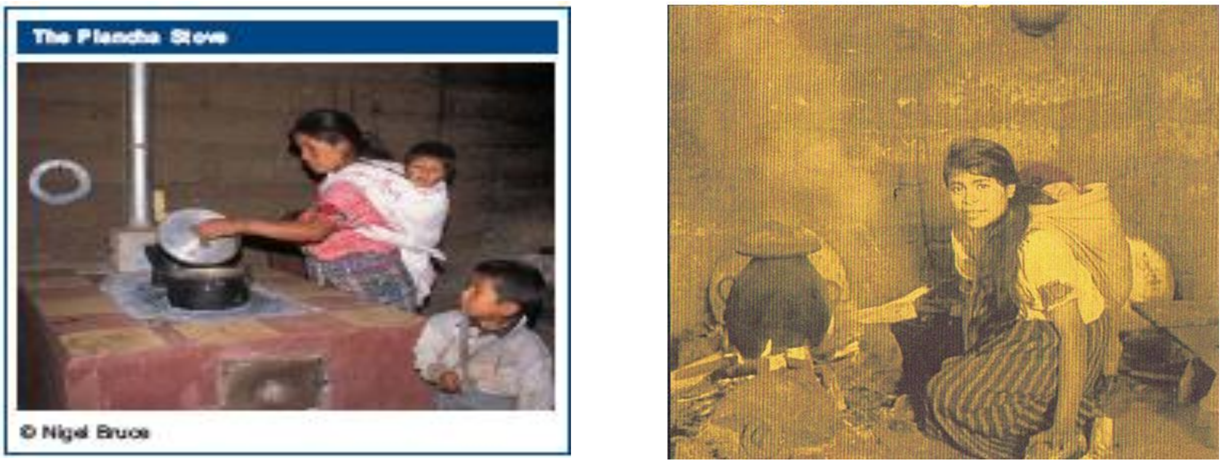
(a)

(b)

Photo 3 Young mother cooking with her young child in a closed kitchen (Dasgupta et al., 2004).

The killer in the kitchen

Photo 4a & b Young mothers cooking with their children



(a) Waist high, stove with flue (WHO, 2005b)

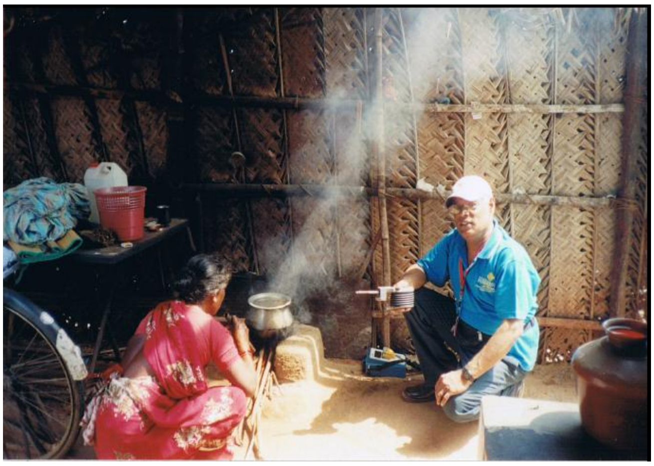
(b) Three stone stove without flue (WHO, 2006b)

Photo 5c Open fire in outdoor cooking in Pakistan (WHO, 2005b).

(c)

Appendix M

Photos 1 Data collecting in Tamil Nadu in South India



(a) Indoor cooking & CO monitoring

(b) Researcher with wood salesperson

(c) Indoor cooking & $PM_{2.5}$ monitoring

(d) Boiling water outdoors & monitoring

(e) Indoor cooking with children

(f) Questionnaire survey

(g) Women using textile wastes

(h) Indoor kitchen in a bad condition

(i) Different types of housing with one room, cooking normally indoors

(j) My son with same age local children

(k) Outdoor burning at the back

(l) A fifty-one-year-old grandmother

(m) A thirty-seven-year-old mother

(n) Mother and daughter collecting firewood