CHAPTER I

INTRODUCTION
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SECTION I

BACKGROUND OF THE STUDY

1.1.1 INTRODUCTION

1.1.1.1 Research areas: India and Thailand

INDIA

Figure 1: Map of India

1.1.1.1 (a) India introduction: geographical profile

In the first section of the first part, research area the researcher intends to present the general background of the two countries the researcher has purposively selected to study the interesting and enlightening research topic related to health science. The background information begins with India, the country that covers an area of 3.28 million sq kms. It
is the seventh largest country in the world. The mainland of India extends between 8° 4’
N and 37° 6’ North Latitude and 68° 7’ and 97° 25’ East Longitudes. The Tropic of
Cancer 23° 30’ N divides India almost into two halves. The land frontier of the country
is 15, 200 kms and the total length of the coastline is over 7, 500 kms. India is divided
into 28 states. The capital of India is Delhi and the largest state in size is Maharashatra.
The Indian Census began in 1872 and it is the largest source of statistics about the
people of India. It brings out statistics every 10 years. For scholars and researchers, the
Indian Census is an interesting data source. The census is available on various subjects:
Population, Economy, Finance, Literacy, Sex ratio etc. There are sub topics in each
subject, which deal with specific issues of that subject. IMR Rate (Infant Mortality
Rate), Birth Rate, death Rate in Population, Workers in Various sectors, Male Workers,
Female Workers, etc, in Economy, Female Literacy, Male Literacy in Literacy and so
on.  

1.1.1.1 (b) India - the historical profile

In addition, India carries a rich cultural legacy, it was one of the few of the early centers
which saw the emergence of civilizations along with Mesopotamia, Egypt and China.
The period of early civilization was followed by the Vedic Age, the period of
Janapadas, the emergence of Mauryas, Guptas and the Deccan kingdoms. The 16th
century saw the emergence of Mughals who were overthrown by the might of British
imperialistic powers. This segment provides an insight into different aspects of Indian
history.
1.1.1.1 (c) India: a democratic republic

Furthermore, India is a federal republic. The Parliament, known in Hindi as ‘Sansad’ is the highest legislative body of the state. It is divided into the two houses of lower house of elected representatives and upper house called the Lok Sabha and the Rajya Sabha respectively. The Lok Sabha is composed of representatives of people chosen by direct election on the basis of Universal Adult Suffrage. The country has been divided into 543 Parliamentary Constituencies. The Rajya Sabha members are chosen by the elected members of the state and territorial assemblies. The individual states’ have their own governing body. These are known as Vidhansabha (Legislative assembly). The representatives are elected by direct election on the basis of Universal Adult Suffrage.²

1.1.1.1 (d) India - strengths and drawbacks

Moreover, need is the mother of invention, is a proven maxim in sciences, majority of times, social needs have been the primary impetus for technological progress in society. Technological advances in India can be traced back to the remains of Harappan Civilization, with the existence of well-organized urban cluster and a complete drainage system. India has progressed a lot in this field, and it has now fully entered the modern industrial era. Science and technology in India covers all the major branches of human knowledge and activities, including mathematics, astronomy, physics, chemistry, information technology, medical science, architecture and fine arts. Despite such progress India has the biggest slum population in the world which resides in the slum areas distributed in all the parts of India. In addition to this more than 60 percent of Indian people are illiterate and belong to the low socioeconomic status and suffer from educational and social inequalities including poverty-stricken slum population that are
poor, living in clouded and households crowded and with poor nutrition which affect quality of life and health.²

1.1.1.1 (e) The profile of Pune city:

Pune is a city located in the western Indian state of Maharashtra. It is the capital of Pune District in which it is located. It is the 8th largest city in India, and the second largest in the state of Maharashtra. It is located roughly 160 kilometres east of Mumbai at an altitude of 560 metres above sea level, along the eastern edge of the Western ghats on the Deccan plateau.³ It is located at the confluence of Mula and Mutha rivers, which are tributaries of the Bhima Pune is located at 18°32' North 72° 51' East, near the western margin of the Deccan Plateau. The temperatures in summer range from 35 to 39°C (95 to 102°F). Nevertheless, the nights in Pune are significantly cooler compared to most other parts in this region owing to its high altitude. According to the 2001 census
provisional counts, the urban agglomeration around Pune has a population of 4,485,000 in 2005. This figure includes the population of the city of Pimpri-Chinchwad, which is the industrial twin of Pune. Of late, the city has witnessed a sizeable investment in the software and automobile sectors, resulting in an influx of skilled labor from all over India. Several suburbs are now completely cosmopolitan and real-estate prices have boomed since 2003.⁴

Residents of Pune are referred to as Puneites, or as Punekars in the local language Marathi. Marathi is spoken extensively, while English is popular amidst the college-goers, white-collar professionals and other cosmopolitan populace. Hindi and Gujarati are also spoken by many. Gujarati business communities have also established their business.⁴ Pune is one city which embraces people of various ethnic races not only from India but also from different part of the world. However, Pune district has a large slum population as in many other any parts of India which are marked by clouded living, poor socioeconomic status and nutrition that increase morbidity and mortality.

**THAILAND**

![Map of Thailand](image)

**Figure 3:** Map of Thailand⁵
1.1.1.1 (f) Thailand introduced:

The second research area is a province in Thailand and therefore the background information about Thailand is presented. Thailand is a Southeast Asian, predominantly Buddhist Kingdom almost equidistant between India and China. For centuries known by outsiders as Siam, Thailand has been something of a Southeast Asian migratory, cultural and religious crossword. Thailand is divided into 76 provinces, which are grouped into 5 groups of provinces by location i.e. North, Northeast, East, Central and South. Thailand is home to several distinct geographic regions, partly corresponding to the provincial groups. The north of the country is mountainous, with the highest point being the Doi Inthanon at 2,576 m. The northeast consists of the Khorat Plateau, bordered to the east by the Maekhong River. The Centre of the country is dominated by the predominantly flat Chao Phraya river valley, which runs into the Gulf of Thailand. The South consists of the narrow Kra Isthmus that widens into the Malay Peninsula.6

1.1.1.1 (g) Public health in Thailand through centuries:

Public health in Thailand has been developed from the past to the present. In the rule of the Chakkri Dynasty it has been the era of foundation and revival of public health. The King Rama III (1828-1850) had the medical recipes inscribed on the wall of Chetupol Temple, including the symptoms and the ways of treatment, so that the people could study and learn how to treat themselves. It was believed that Chetupol temple was the first open University in Thailand. During the reign of King Rama IV (1851-1868) the medicine was clearly divided into two ways; traditional treatment and scientific treatment. In the reign of King Rama V (1868-1910) the nursing department was established in order to control Sririraj hospital (the main hospital located in Bangkok)
and other hospitals. It was held that this was the new era of the modern medicine and public health. During the reign of King Rama VI many hospitals, medical schools, and nursing schools were established. He also gave up Thai traditional treatment. In 1932 the Ministry of Public Health was established by The Field Marshal, the prime minister, in the reign of King Rama VII. In the reigns of King Rama VIII and King Rama IX (the present King) the public health and medicine have been prominently developed because their late father, Mahitalathibet Adulyadetwikrom, devoted most of his time for medicine and public health. He studied and got the certificate of medicine and public health from Harvard University. After he came back to Thailand, he devoted the rest of his life for public health such as donating some money for medicine schools, supporting scholarship for doctors and nurses to study abroad, establishing nursing academic development project, being the lecturer of public health training etc. He was named as the Father of modern medicine and public health.6

1.1.1.1 (h) Life-span, birth-rate and literacy:

In the past, public health worked appropriately. Ten years ago, the mean age for man has increased from 57 years to 65 years and for woman from 61 years to 77 years. The birth rate has decreased by 1.04% per year and has continued to decrease each year. The death rates have decreased from 5.1/100 to 4.1/100. Mostly, Thai people complete their schooling and become graduates. Few Thai people are illiterate which is found in slum area in the big cities in Thailand such as Bangkok metropolitan area and some provinces in the North Eastern part of Thailand but not found in Chiang mai province.7
Chiang Mai is the second-biggest province (changwat) of Thailand, located in the north of the country. Its neighboring provinces are (from north-east clockwise) Chiang Rai, Lampang, Lamphun, Tak and Mae Hong Son. In the north it borders Myanmar. The area is 20,107.0 km$^2$, is located 310 m (1027 ft) above the sea level. The district of Chiang Mai is covered by many mountains, usually stretching in the south-north direction. The river Ping, one of the major tributaries of the Chao Phraya River, originates in the Chiang Dao mountains. The highest mountain of Thailand, the 2,575 meter high Doi Inthanon, is located in the district. Several national parks are located in the district: Doi Inthanon, Doi Suthep-Pui, Mae Ping, Sri Lanna, Huay Nam Dang, Mae Phang, Chiang Dao.

The city of Chiang Mai was capital of the kingdom of Lanna after its founding in 1296. In 1599 the kingdom lost its independence and became part of the Ayutthaya kingdom.
In 1932 the province Chiang Mai became the second level subdivision of Thailand when the administrative unit of Monthon Phayap, the remains of the Lanna kingdom, was dissolved. Chiang Mai is subdivided into 22 districts (Amphoe) and 2 minor districts (King Amphoe). The districts are further subdivided into 204 communes (tambon) and 1915 villages (muban). In 2007, Chaing Mai inhabitants numbered 1,649,457. The population density is 82.03 inh./km², 13.4% of the population in the province are members of the hill tribes, among them the Hmong, Yao, Lahu, Lisu, Akha and Karen. Chiang Mai people complete their schooling and become graduates. There are no illiterates in Chiang Mai and there is no slum area in Chiang Mai.

MUANG AND SARAPHI DISTRICT

![Map of Muang and Saraphi districts](image)

Figure 5: Map of Muang and Saraphi districts

1.1.1.1 (j) Muang and Saraphi districts in Chiang Mai province

Muang and Saraphi districts are two of the 22 districts of Chiang Mai province with no number of the hill tribes. Muang district has an area of 203.5 km², and is situated 291 m (958 ft) above the sea level and comprises of eleven subdistricts while Saraphi district
has an area of 97.5 km², and is situated 284 m (935 ft) above the sea level and comprises of ten subdistricts. In June 2008, the total population of Muang was 118,949, 57,074 males, 61,875 females. The population density is 584.3 inhabitants/km². The major occupation in Muang is trading by merchants and office-based work. The total population of Saraphi was 75,454, 35,811 males, 39,643 females. The population density is 774 inhabitants/km². The major occupation in Saraphi is farming and longan gardening.

1.1.1.2 Indoor air pollution exposure

1.1.1.2 (a) Indoor air pollution:

Indoor air pollution can be traced to prehistoric times when humans first moved to temperate climates approximately 200,000 years ago. These cold climates necessitated the construction of shelters and the use of fire indoors for cooking, warmth and light. Ironically, fire, which allowed humans to enjoy the benefits of living indoors, resulted in exposure to high levels of pollution as evidenced by the soot found in prehistoric caves. It has been estimated that approximately half of the world’s population, and up to 90% of rural households in developing countries, still rely on biomass fuels. Biomass when burnt indoors in open fires or poorly functioning stoves leads to levels of air pollution that are among the highest ever measured.

1.1.1.2 (b) Biomass fuel:

The developed countries use primary petroleum products and electricity for cooking and other purposes but this is not the case of developing countries such as India and
Thailand. Inspite of rapid development, major fuel used in most developing countries is biomass fuel.\textsuperscript{15} Biomass fuel is made of solid fuels, which are less efficient and take larger quantities of peat, wood, or coal, are quick to emit as similar energy as liquefied petroleum gas (LPG). Biomass fuel produces larger quantities of smoke when they are burned. Solid fuels produce dramatically less heat for the amount of fuel consumed and produce dramatically more pollution (see the shift of energy in fig. 6).\textsuperscript{16} Although in recent times cleaner and more sophisticated fuels are available in developing countries, households continue to use biomass because of low cost and easy availability.\textsuperscript{15} The global energy derived from biomass fuels has fallen from 50\% in 1900 to nearly 13\% in 2000, but recently it seems to be increasing, especially amongst the poor and also people living in rural area. The current socioeconomic situation in many developing countries suggests that the use of biomass fuels will continue in the coming decades.\textsuperscript{17} In these countries, nearly 2 billion kilograms of biomass are burned every day.\textsuperscript{18} In rural India, nearly 90\% of the primary energy is derived from biomass (wood, 56\%; crop residues, 16\%; dung, 21\%).\textsuperscript{19} The total annual average of wood production used for fuel in developing countries increased approximately 16.5\% over the past decade to about 1.6 billion cubic meters.\textsuperscript{20}

1.1.1.2 (c) Energy ladder:

Although the portion of global energy derived from biofuel has fallen, this trend has leveled and there is evidence that biofuel use is increasing among the poor.\textsuperscript{13} Poverty is one of the main causes to the adoption of cleaner fuels and slow and rising fuel price in
many countries implies that biofuels will continue to be used by the poor for many more decades.\textsuperscript{14}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{energy_ladder.png}
\caption{Energy ladder\textsuperscript{16}}
\end{figure}

1.1.1.3 Indoor air pollution and cooking fuel

1.1.1.3 (a) Burning fuels:

Majority of indoor air pollution is primarily emitted from burning solid fuels especially, from the use of solid fuels for cooking. Most rural households in the poorest developing countries utilize solid fuels for their everyday energy needs.\textsuperscript{22} Solid fuel use is defined as the combustion of coal or biomass (wood, dung, charcoal and crop residues). Commonly, open fires or inefficient simple stoves are used, often in poorly ventilated conditions. Burning of biomass fuel essentially emits array of health damaging pollutants such as PM, CO, SO\textsubscript{2} and various nitrogen compounds which increase in the indoor environment to such an extent that their exposures and their inhalation result in
such vast proportions that are orders of magnitude higher than international guidelines, and higher than exposures encountered outdoors in even heavily polluted areas.\textsuperscript{22,23}

1.1.1.3 (b) Toxic indoor air pollutants:

In the past, and even today, most research emphasizes outdoor air pollution. Yet despite being somewhat neglected, indoor air pollution poses far greater health risk than outdoor air pollution. Although outdoor sources often dominate air pollution emissions, indoor sources frequently dominate air pollution exposures, since exposure is a function of both the concentrations in an environment, and the person-time spent in the environment.\textsuperscript{22,24} The major toxic indoor air pollutants and sources are shown in Table 1.

Table 1: Major toxic pollutants of indoor air

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Major indoor sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Fine particles</td>
<td>Fuel/tobacco combustion, cleaning, fumes from food being cooked, e.g. from cooking oil</td>
</tr>
<tr>
<td>• Carbon monoxide</td>
<td>Fuel/tobacco combustion</td>
</tr>
<tr>
<td>• Polycyclic aromatic hydrocarbons</td>
<td>Fuel/tobacco combustion, fumes from food being cooked, e.g. from cooking oil</td>
</tr>
<tr>
<td>• Nitrogen oxides</td>
<td>Fuel combustion</td>
</tr>
<tr>
<td>• Sulfur oxides</td>
<td>Coal combustion</td>
</tr>
<tr>
<td>• Arsenic and fluorine</td>
<td>Coal combustion</td>
</tr>
<tr>
<td>• Volatile and semi-volatile organic compounds</td>
<td>Fuel/tobacco combustion, consumer products, furnishings, construction materials, fumes from food being cooked, e.g. from cooking oil</td>
</tr>
<tr>
<td>• Aldehydes</td>
<td>Furnishing, construction materials, cooking</td>
</tr>
<tr>
<td>• Pesticides</td>
<td>Consumer products, dust from outside</td>
</tr>
<tr>
<td>• Asbestos</td>
<td>Remodelling/demolition of construction materials</td>
</tr>
<tr>
<td>• Lead</td>
<td>Remodelling/demolition of painted surfaces</td>
</tr>
<tr>
<td>• Biological pollutants</td>
<td>Moist areas, ventilation systems, furnishings</td>
</tr>
<tr>
<td>• Free radicals and other short-lived, highly reactive compounds</td>
<td>Indoor chemistry</td>
</tr>
<tr>
<td>• Radon</td>
<td>Soil under building, construction materials</td>
</tr>
</tbody>
</table>

From: Indoor air quality handbook (2001).\textsuperscript{25}
1.1.1.3 (c) Respirable particulate matter:

Supporting evidence for health effects associated with exposure to smoke from biomass combustion is provided by studies on outdoor air pollution, as well as by studies dealing with exposure to environmental tobacco smoke. Criteria documents for outdoor air pollutants published by the USEPA detail the health effects of many pollutants such as particulate matter, carbon monoxide, oxides of sulfur and nitrogen, and polycyclic aromatic hydrocarbons (PAHs).\(^{26}\) Respirable particulate matter is now considered the single best indicator pollutant for assessing the overall health-damaging potential of most kinds of combustion, including that of biomass. Considerable scientific understanding now exists on the aerodynamic properties of these particles that govern their penetration and deposition in the respiratory system.

1.1.1.3 (d) Health effects of particles

The health effects of particles deposited in the airways depend on the defense mechanisms of the lung, such as aerodynamic filtration, mucociliary clearance, and in situ detoxification. Since most particulate matter in biomass fuel smoke is less than 2\(\mu\)m in diameter, it is possible that such particulate matter may reach the deepest portions of the respiratory tract and alter defense mechanisms. Several biomass fuel combustion products may also impair mucociliary activity and reduce the clearance capacity of the lung, resulting in increased residence time of inhaled particles, including microorganisms. \textit{In situ} detoxification, the main mechanism of defense in the deepest non-ciliated portions of the lung, may also be compromised by exposure to components of biomass fuel smoke.\(^{27}\)
1.1.1.3 (e) Other pollutants – carbon monoxide (CO), sulfur dioxide (SO₂), nitrogen dioxide (NO₂), polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds

Carbon monoxide binds to hemoglobin in preference to oxygen and thus reduces oxygen delivery to key organs, which may have important implications for pregnant women, with developing fetuses being particularly vulnerable. Although emissions of sulfur dioxide and nitrogen dioxide are of lesser concern in biomass combustion (high levels of sulfur dioxide may be reached with other solid fuels such as coal), they are known to increase bronchial reactivity. PAHs such as benzo[a]pyrene are known carcinogens. Volatile organic compounds in biomass smoke, such as formaldehyde, benzene, 1–3 butadiene, styrene, and xylene, are known or suspected carcinogens. Some of the earliest human evidence linking indoor air pollution from biomass combustion with respiratory health came from studies carried out in Nepal and India in the mid-1980s. Since then, there has been a steady stream of studies, especially on women who cook with these fuels and young children. Associations between exposure to indoor air pollution and increased incidence of chronic bronchitis in women and acute respiratory infections (ARI) in children have been documented.

Many recent studies have also been conducted in rural Indian villages.

1.1.2 SOURCES, USES AND POLLUTANT EMISSIONS OF BIOMASS FUELS

1.1.2 (a) Sources of Biomass Fuels:

Biomass fuel, or biofuel, refers to any plant or animal based material deliberately burned by humans. Wood is the most common biofuel, but use of animal dung and crop
residues is also widespread. The types of fuels used typically increase in cleanliness, convenience, efficiency and cost as people move up what has been termed the “energy ladder” (see fig. 6). Dung and crops are on the lowest range of the ladder progressing to wood, charcoal, kerosene, LPG, and finally electricity. People generally move up the ladder as socio-economic conditions improve. Other sources of indoor air pollution in developing countries include smoke entering the home from nearby houses, burning of forests, agricultural land and household waste, the use of kerosene lamps, and industrial and vehicle pollution. Additionally, environmental tobacco smoke (ETS), is another source of indoor air pollution exposures which can be expected to increase in importance in developing countries. It is important to recognize that the open hearth and resulting smoke often have considerable cultural and practical value in the home, including control of insects, lighting, drying food, fuel and housing materials and for flavouring foods.

1.1.2 (b) High Emissions

Biomass smoke contains many thousands of substances, many of which damage human health. Most important are particulates, carbon monoxide, nitrous oxides, sulphur oxides (more with coal), formaldehyde, and polycyclic organic matter which include carcinogens such as benzo[a]pyrene. Small particles of diameter less than 10 microns (termed PM10), and in particular those less than 2.5 microns (PM 2.5), are able to penetrate deep into the lungs and appear to have the greatest health-damaging potential. In most of the stoves, combustion is very much incomplete and results in high emissions which combine with often poor ventilation to produce very high levels of indoor pollution. The particulate matter levels in rural homes of developing countries
exceed safety stands recommended by the WHO on a daily basis by a factor of ten, twenty and sometimes more. It should be noted that the revised WHO air quality guidelines do not quote values for PM$_{10}$, because there is growing evidence that there is no safe lower limit of exposure. Accordingly, exposure-response data for mortality and morbidity outcomes are presented. Health effects are determined not just by the pollution level, but more importantly by the time people spend breathing polluted air – in other words the exposure level. Exposure refers to the concentration of pollution in the immediate breathing environment over a specified time interval.

1.1.2 (c) Risks Due To Air Pollution Exposure

In developing countries, individuals are typically exposed to these very high levels of pollution for between 3 and 7 hours each day over many years. During winter in the many cold and mountainous areas, exposure may occur over a substantial portion of each 24 hour period. Cultural practices common in developing countries may promote exposure of infants, women, the elderly and the sick. Since it is the women who generally cook, their exposure is much higher than men. Young children are often carried on their mother’s back while she is cooking, so that from early infancy, children spend many hours breathing smoke. Table 2 summarizes the most important health damaging pollutants in biomass and coal smoke, the mechanisms involved and potential health consequences.
Table 2: Mechanisms by which some key pollutants in smoke from domestic sources may increase risk of respiratory and other health problems

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Mechanism</th>
<th>Potential health effects</th>
</tr>
</thead>
</table>
| • Particulate matter: small particles less than 10μm, and particularly those less than 2.5μm aerodynamic diameter | • Acute: bronchial irritation, inflammation and increased reactivity  
• Reduced mucus-ciliary clearance  
• Reduced macrophage response and reduced local immunity  
• Fibrotic reaction  
• Autonomic imbalance,  
• Pro-coagulant activity,  
• Oxidative stress | • Wheezing, exacerbation of asthma  
• Increased susceptibility to respiratory infections  
• Development of COPD  
• Exacerbations of COPD  
• Low birth weight (fetal COHb 2-10%, or higher)  
• Increase in perinatal deaths |
| • Carbon Monoxide | • Binding with Haemoglobin (Hb) to produce COHb which reduced O2 delivery to key organs and the developing fetus. | • Lung cancer  
• Cancer of mouth, nasopharynx, and larynx |
| • Benzo[a]pyrene | • Carcinogenic (one of a number of carcinogenic substances in coal and biomass smoke) | • Increased susceptibility to infections  
• Development of asthma |
| • Formaldehyde | • Nasopharyngeal and airway irritation  
• Increased allergic sensitisation | • Wheezing and exacerbation of asthma  
• Increased susceptibility to respiratory infections  
• Reduced lung function |
| • Nitrogen dioxide | • Acute exposure increases bronchial reactivity  
• Increased susceptibility to bacterial and viral lung infections | • Wheezing and exacerbation of asthma  
• Increased susceptibility to respiratory infections  
• Reduced lung function |
| • Sulphur dioxide | • Airway irritant  
• Increases bronchial reactivity | • Wheezing and exacerbation of COPD and cardiovascular disease  
• Exacerbation of COPD and cardiovascular disease |
| • Biomass smoke (component uncertain) | • Absorption of toxins into lens, leading to oxidative changes | • Cataract |

From: Revisions to the National Ambient Air Quality Standards for Particulate Matter.²⁶

1.1.3 THE HEALTH EFFECTS OF INDOOR AIR POLLUTION EXPOSURE IN DEVELOPING COUNTRIES

1.1.3 (a) Polluted Air Causes Health Hazards

Basically, clean air is a fundamental need for good health. Everybody breathe approximately 10,000 litres of air each day, out of which around 400 litres of oxygen is extracted from the lungs for the life giving metabolic processes in the body. If the air which we breathe is polluted it can affect the health of the lungs or other body organs.⁴⁷

Air pollution is caused mainly by burning wood, coal, oil, petrol or other fuels, but it can also come from factories or spraying of pesticides. In rural areas, where open fires
or simple stoves without proper chimneys are used for cooking, smoke indoors can be a significant health risk. In urban areas, factory and household chimneys used to be the biggest polluters, but increasingly the exhaust fumes from motor vehicles have become a real health threat.\textsuperscript{48}

1.1.3 (b) Exposure-Response Relationship

A recent study has characterized the exposure–response relationship between biomass smoke exposure and acute respiratory infection in children of rural Kenyan households\textsuperscript{49}. Odds ratios in the range of 2–5 for incidence of acute respiratory infections in children exposed to biomass smoke have been reported.\textsuperscript{50} Although most studies on the health effects of biomass combustion have been observational in nature and have relied on proxy measures of exposure (such as reported hours spent near the stove, years of cooking experience, or child being carried by mother while cooking), the consistency of evidence from studies exclusively carried out in developing countries, together with supportive evidence provided by outdoor air pollution and environmental tobacco smoke studies, indicates that there is likely to be a strong association between indoor smoke exposure and acute respiratory infections in children and chronic bronchitis in women.\textsuperscript{51}

1.1.3 (c) Health Outcomes – Acute Lower Respiratory Tract Infection, Asthma, Blindness (Cataracts), COPD, Lung Cancer (Coal Only) and Tuberculosis

The evidence for other health outcomes including acute lower respiratory tract infection, asthma, blindness (cataracts), COPD, lung cancer (coal only) and tuberculosis needs additional strengthening from studies that have better indicators for exposure and
control for confounders. Associations with adverse pregnancy outcomes (including low birth weight and stillbirth) and ischemic heart disease are biologically plausible. They have been associated with outdoor air pollution and smoking (passive and active). They have not yet been adequately explored for exposures from use of solid household fuels. Table 3 shows relative risk estimates for health outcomes that are associated with exposure to smoke from solid fuel use.

1.1.3 (d) Magnitude of Hazards

Based on this evidence, it has been estimated that the indoor air pollution contributes to 3–5 per cent of the national burden of disease in India. More specifically, some 440,000 premature deaths in children under 5 years, 34,000 cases of chronic respiratory disease in women under 45 years, and 800 cases of lung cancer may be attributable to solid fuel use every year. A recent WHO analysis done for the year 2000 as part of the global chronic respiratory attributable exercise has determined slightly smaller risks, but they lie in the same range; i.e., about 400,000 premature deaths annually in India. Despite the magnitude of the problem of indoor air pollution, the health impact of this environmental exposure has yet been relatively neglected by research, donors and policy makers.

Table 3: Health effects of exposure to smoke from solid-fuel use: plausible ranges of relative risk in households using solid fuel

<table>
<thead>
<tr>
<th>Health Outcome</th>
<th>Population Affected</th>
<th>Relative Risk</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>† Acute lower respiratory tract infection</td>
<td>Females &lt;5 yrs</td>
<td>Low 2.0</td>
<td>High 3.0</td>
</tr>
<tr>
<td>† Asthma</td>
<td>Females &gt;15 yrs</td>
<td>1.4</td>
<td>2.5</td>
</tr>
<tr>
<td>† Blindness (cataracts)</td>
<td>Females &gt;15 yrs</td>
<td>1.3</td>
<td>1.6</td>
</tr>
<tr>
<td>† COPD</td>
<td>Females &gt;15 yrs</td>
<td>2.0</td>
<td>4.0</td>
</tr>
<tr>
<td>† Lung cancer (coal only)</td>
<td>Females &gt;15 yrs</td>
<td>3.0</td>
<td>5.0</td>
</tr>
<tr>
<td>† Tuberculosis</td>
<td>Females &gt;15 yrs</td>
<td>1.5</td>
<td>3.0</td>
</tr>
</tbody>
</table>

From: Adapted from Smith (2000).
1.1.3 (e) Respiratory Infections

There is now consistent evidence that biomass smoke exposure increases the risk of childhood acute respiratory infections, particularly pneumonia, and probably otitis media in women who are concerned with cooking and burning, and acute respiratory infections, particularly pneumonia, and otitis media in women who are exposed during cooking. An association between smoke exposure with chronic bronchitis (assessed by symptoms) and chronic obstructive pulmonary disease (assessed clinically and by spirometry) is well established, particularly among women. In line with findings for environmental tobacco smoke, there is emerging evidence that exposure during pregnancy reduces birth weight, possibly mediated through increased carbon monoxide. Infant and perinatal mortality has also been reported to have increased. Furthermore, biomass smoke exposure has been shown to exacerbate asthma, although the evidence is limited and conflicting. A number of studies have also shown evidence of an increased risk of pulmonary tuberculosis. Finally, human and animal studies suggest an increased risk of cataract.

1.1.4 INDOOR AIR POLLUTION EXPOSURE AND WOMEN'S HEALTH

1.1.4 (a) Women and Children Exposed:

Because biomass fuel still continues to be used in around 50% of homes worldwide, it is estimated that 3 billion people are exposed to indoor smoke from the burning of biomass fuel and are at risk for its adverse respiratory effects. Women, young girls, and small children are exposed for the longest duration because they spend more time in proximity to the biomass smoke. In developing countries, girls start cooking at the age
15 years and spend an average of 4 to 6 hours daily in the kitchen, usually an enclosed space with poor ventilation. Therefore, during their life time, women are exposed to biomass smoke for 30 to 40 years, which is equivalent to approximately 60,000 hours of exposure^55 or inhaling a total volume of 25 million litres of polluted indoor air.

1.1.4 (b) Serious Health Burden:

The health burden from indoor air pollution is the greatest in high-altitude rural areas and amongst poor families who tend to use cheap bio-mass in primitive stoves without proper ventilation. Women and young children are at the greatest risk because their gender roles and household responsibilities and cooking-behaviors result in high exposure to indoor air pollution (85% of all global particulate exposure occurs indoors)^56.

Bio-mass is extremely polluting that poses serious health hazards due to acute and chronic exposure to particulates (PM$_{10}$), sulfur and nitrous oxides (SO$_2$, NO$_x$), carbon monoxide (CO), fluoride (coal), aldehydes and para amino hydrocarbons (PAHs). Developing countries account for 77% of all global particulate exposure, where numerous studies have found that indoor air pollution levels are typically many times higher than developed world standards for ambient air quality. Concentration levels vary greatly depending on the time of day, season and place of measurement, especially for inhalable particulates (10) and CO levels. Use of biomass causes respiratory and other illnesses. It also has implications for household safety (burns and disfiguration, fire), allocation and use of the time of household members, especially women^56.
1.1.4 (c) Ill-Effects of Acute Exposure:

While acute exposure to smoke may result in carbon monoxide poisoning and death, most of the effects occur as a result of long term exposure. There is strong evidence that chronic exposure to indoor air pollutants increases the risk of respiratory illnesses, such as respiratory tract infection, chronic obstructive pulmonary disease including increased susceptibility to asthma.\textsuperscript{56}

The above-mentioned facts indicate, therefore, to concentrate on the respiratory health due to indoor air pollution which is caused by type of cooking fuel, ventilation, cooking time, smoking status and dampness of wall and other factors among women who are exposed to high levels of biomass fuel smoke during the entire span of life time.
SECTION II

CLARIFICATION OF STUDY

1.2.1 STATEMENT OF THE PROBLEM

1.2.1.1 Introduction

The second section of the first Chapter is devoted to the statement of the research problem and other methodological details.

Indoor air quality and indoor air pollutants are now recognized as a potential source of health risks to the exposed population throughout the regions of the world. The use of open fires for cooking and heating exposes an estimated 3 billion people in the world to enhanced concentrations of particulate matter and gases, up to 10-20 times higher than ambient concentrations. Indoor air pollution is a major factor associated with respiratory health in both rural and urban areas of developing countries. A pollutant released indoors is often more dangerous to human health than a pollutant released outdoors. The combustion of biomass fuels in poorly ventilated kitchens using poorly functioning stoves leads to the release of high concentrations of respirable particulates, gases including carbon monoxide, sulfur dioxide, nitrogen oxides, toxic compounds like benzene and formaldehyde, and polycyclic aromatic compounds such as benzo-a-pyrene. Exposure to these pollutants has been shown in many recent studies to be causally linked to several health effects especially in women who cook with these cooking fuels and young children, as they spend long periods of time indoors.
1.2.1.2 Indoor air pollution in India and Thailand

The 1991 Indian National Census included for the first time a question about the primary household fuel used and reflected that about 95% of the rural population still relied primarily on biomass fuels (dung, crop residues, and wood). A small fraction uses coal, which means about 97% of households relied principally on these unprocessed solid fuels. Nationwide, some 81% of all households relied on these fuels; 3% used coal and 78% used biomass. An independent probability-weighted national survey of 89,000 households in 1992 derived very similar results.\(^\text{61}\)

Cooking and heating with solid fuels such as dung, wood, agricultural residues or coal is the largest source of indoor air pollution. When used in open cooking stoves, the fuels emit substantial amount of pollutants including particles that are inhaled without hindrance, like carbon monoxide, nitrogen, sulfur dioxides and benzene. Tobacco smoke increases the burden of indoor air pollution. An estimated 500,000 women and children die in India each year due to indoor air pollution-related causes.\(^\text{15}\) According to data obtained during the 1991 National Census which included for the first time a question about the primary household fuel used and reflected that about 95% of the rural population still relied primarily on biomass fuels (dung, crop residues, and wood). A small fraction uses coal. About 97% of households relied principally on these unprocessed solid fuels. From the 81% of all households relied on these fuels; there were 3% that used coal and the remaining 78% used biomass. An independent probability-weighted national survey of 89,000 households in 1992 has produced very similar results.\(^\text{62}\) Biomass fuel is confirmed to be a source of air pollution.

Recent studies in India showed that non-smoking women cooking on open fires show a greater incidence for developing chronic lung diseases. Assessments of the burden of
disease attributable to use of solid fuel use in India have put the figure at 4-6 percent of
the national burden of disease.\textsuperscript{58} Although there is evidence of high pollution levels in
the indoor environment, there is a poor understanding of the multiple household
variables such as the type of cooking fuel, location of kitchen, and type of stove on
actual exposures, resulting in considerable ambiguity in understanding the exposure–
response relationship.\textsuperscript{61}

Indoor air pollution due to cooking fuel is not as big a problem in Thailand, as in India.
According to data obtained during the 2006 International Household Survey Network,
in Thailand, 55.3% of households relied on LPG, remaining rely on charcoal (17.5%),
wood (16.8%), electricity (3.2%), and agricultural crop residues (0.1%), respectively
while half of rural households relied on biomass fuel for cooking compared to LPG.\textsuperscript{63}
Furthermore, most of the stoves in every household are either closed stoves or efficient
stoves (94.3%), there are only few that use open stove (4.2%) and open fire (1.4 %).\textsuperscript{64}
Since Thai households use efficient fuels and efficient stoves in more than 90% of
homes they produce much lesser pollution.

In Thailand, ambient air pollution is a bigger problem than indoor air pollution,
especially in the large provinces that have a high density of population, for instance,
Bangkok metropolis, Chiang Mai province, Nakornrashsrima province.

Chiang Mai is the largest province in the Northern part of Thailand. It has a population
of approximately 1.4 million people. Chiang Mai’s outdoor air quality has been steadily
deteriorating over the past ten years. This is, in part, seen in every city that intends to
increase its economic growth, without considering the environmental impact. One
obvious answer lies in the prevalence of burning in the city, be that in cremations, or
just burning off garbage, forest fires or vehicular emissions. Add to that dusts raised
during building and excavations. Chiang Mai province’s problems are exacerbated by
the fact that the city is located in a natural bowl that results in the same air being re-circulated, picking up more particulates every time. The Pollution Control Department reported that at Muang district in Chiang Mai province in March 2007, PM$_{10}$ reached levels of 250 mcg./m$^3$ as compared to the WHO safety limits of 120 mcg./m$^3$. In general, PM$_{10}$ levels in Chiang Mai province have been reported to reach levels that are double the “safe” limits set by United States Environmental Protection Authority. It does not end there. According to the research study by Associate Prof. Dr. Utsanee Winichkhetkamnuan and Dr. Karmen, the expert from Fulbright, USA, it was found that some places in Chiang Mai province such as the central part of Muang district in Chiang Mai province have dusts four times higher than these recorded levels.

Air pollution can be called the “Silent killer” and affects all Chiang Mai residents’ health without their realizing it. Prof. Sumittra Thongprasert claims that the incidence of lung cancer in Chiang Mai province is ranked second highest in the world. In addition, admissions for respiratory problems have almost doubled in the past eight years. The research problem is in the discipline of health sciences. It is related to the respiratory health among women. It analyzes the impact of indoor air pollution exposure on respiratory health among women who are subjected to such exposure while cooking. The study covers locations in India and Thailand.

1.2.2 SIGNIFICANCE OF THE STUDY

This study on the impact of exposure to indoor air pollution on respiratory health in women from Pune district, India and Chiang Mai province, Thailand is important for the following reasons:
1.2.2 (a) According to the World Health Organization (WHO) estimates, exposure to indoor smoke from solid fuels is responsible for about 1.6 million premature deaths annually in developing countries and 2.6% of the global burden of disease.\(^{38}\)

1.2.2 (b) Research on indoor air pollution is finally catching up with the size of the health risks posed by this environmental hazard.\(^{59}\) Almost half of the world’s households cook with solid fuels (wood, dung, agricultural wastes) that emit high levels of particulates, carbon monoxide, and other pollutants. In high mortality developing countries, the risk attributable to this indoor air pollution accounts for 3.6% to 3.7% of disability-adjusted life years (DALYs), fourth in importance below underweight, unsafe sex, and polluted drinking water and poor sanitation.\(^{17}\) Furthermore, indoor air pollution has been linked to chronic obstructive pulmonary disease such as asthma, COPD.\(^{67}\) Indoor air pollution is hazardous to health in the same measure as malnutrition, unsafe sex and water pollution are health threats.

1.2.2 (c) There are only a handful of studies that have investigated the consequences of indoor air pollution on respiratory morbidity. Instead, most research has relied on questionnaire measures of fuel sources and respiratory problems. This reliance on proxy rather than physical measures may have reduced the strength of the relationships yet uncovered.\(^{32}\)

1.2.2 (d) On the other hand, household research using physical measures of indoor air pollution or lung function have been limited to small, geographically focused designs. Since many factors of interest, such as housing construction vary far more across regions than within a single village, these designs limit their utility. At the same time, the surveys designed by public health personnel have not been able to incorporate intensive physical measurements required by public health personnel due to cost constraints.\(^{32}\)
1.2.2 (e) In India over the last two decades, although a few dozen studies concerning indoor air pollution exposures associated with biomass combustion have been carried out, they have had small sample sizes and were not done in a way to be statistically representative of the women population in this part of India. Contrarily, although Thailand has routine, qualitative data on exposures, such as by primary fuel type use at homes, that are routinely collected in national surveys such as the Census and National Family Health Survey which indicate these facts. There are no studies that have investigated the impact of indoor air pollution on lung function and exhaled breath carbon monoxide levels.  

There can be little doubt that the exposure to indoor air pollution in developing countries presents a major public health problem for many poor urban and rural communities, but there are no studies that have examined this. Besides, all the reported studies are observational and very few have measured exposure directly, instead relying on proxies such as type of house, type of kitchen, kitchen ventilation, type of cooking fuel, duration of cooking or reported time spent near the fire. Thus, despite mounting evidence that biomass smoke exposure increases the risk of a range of diseases with important implications for public health; COPD, asthma, including respiratory symptoms related to these diseases; cough, phlegm, wheeze, breathlessness, these methodological limitations imply that risk estimates are poorly quantified in the previous studies done in the last few years.  

1.2.2 (g) It is reasonable therefore, to ask why should this research investigate the lung function and lung oxidative stress in women from India and Thailand using different types of areas and cooking fuels. Majority of indoor air pollution primarily arises from burning unheating fuels in the homes for purposes such as cooking and heating. Among
most developing countries the poor section of the low socioeconomic status and rural homes mostly use solid fuels such as wood, dung, charcoal and sometimes crop residues for domestic purposes, essentially includes cooking. In most households in the world it is the woman who spends more time in cooking. On an average, worldwide women spend time of 4 to 6 hours daily in cooking area during their life time. They are the ones who are directly exposed to PM, noxious gas, and different chemicals released by burning fuels in many years. Therefore this study needs to investigate the impacts on respiratory health in different areas such as urban non-slum area which has represented the middle to higher socioeconomic level and good nutrition, urban slum area which has represented the low socioeconomic level, clouded and poor nutrition, and rural area which has represented the low to middle socioeconomic level and good nutrition, and different cooking fuels such as LPG, kerosene and biomass fuel, in women.

1.2.2 (h) The findings of this study will be useful for understanding the relationship between indoor air pollution and respiratory health in women, and if such an observation is found, it will help to create awareness amongst people using different types of cooking fuels and also inform health policy makers to undertake appropriate measures. For Thailand, the findings will increase the data base of spirometry and breath exhaled CO in women. The study has not measured levels of indoor air pollutants.

1.2.3 RESEARCH QUESTIONS

The main question related to the topic of research is:
1.2.3 (a) What is the impact of exposure to different types of cooking fuels in the respiratory health of women residing in and around Pune district, India and Chiang Mai province, Thailand?

1.2.3 (b) The other research questions are those which are the off-shoots of the main research question.

1.2.4 AIMS AND OBJECTIVES OF THE STUDY

1.2.4 (a) To explore the prevalence of respiratory symptoms such as cough, phlegm, wheeze and breathlessness, obstructive airway diseases such as asthma, COPD, and lung oxidative stress in different areas and cooking fuels in women residing in and around in Pune district, India and Chiang Mai province, Thailand.

1.2.4 (b) To explore the association between respiratory health effects (respiratory symptoms/diseases, lung function, and lung oxidative stress) and indoor environmental factors, socioeconomic status and nutritional factors and amongst women residing in and around in Pune district, India and Chiang Mai province, Thailand.

1.2.5 HYPOTHESIS

The hypothesis and the null-hypothesis are stated below:

1.2.5 (a) Hypothesis:

There would be difference in:

a) Respiratory symptoms such as cough, phlegm, wheeze and breathlessness.

b) Prevalence of obstructive airway diseases such as asthma, COPD.
c) Lung function such as % predicted values for FEV₁, FVC, PEFR, FEF₂₅₋₇₅%.

d) Lung oxidative stress.

amongst the women from:

a) Geographical area.

b) Exposed to different cooking fuels such as LPG, kerosene, and biomass fuel.

c) Different socioeconomic status such as education, occupation and annual income.

d) Different indoor environmental factors such as type of house, type of kitchen, kitchen ventilation, type of fuel, duration of cooking, smoking habits (active & passive smoking) and dampness of wall.

e) Different nutritional factors such as type of diet and fruit intake.

1.2.5 (b) Null-hypothesis:

1.2.5 (b) i There is no association between:

1. Different respiratory symptoms/diseases [respiratory symptoms (cough, phlegm, wheeze, breathlessness), asthma and COPD] and indoor environmental factors [type of house, type of kitchen, kitchen ventilation, type of fuel, duration of cooking, smoking habits (active & passive smoking) and dampness of wall].

2. Different symptoms/diseases and socioeconomic status (education, occupation and annual income).

3. Different symptoms/diseases and nutritional factors (type of diet and fruit intake).

1.2.5 (b) ii There is no difference of:
4. Mean difference in % predicted values for FEV₁, FVC, PEFR, FEF_{25-75%} between India and Thailand.

5. Mean difference in % predicted values for FEV₁, FVC, PEFR, FEF_{25-75%} between different types of areas in India (urban non-slum, urban slum and rural area) and Thailand (urban and rural area).

6. Mean difference in % predicted values for FEV₁, FVC, PEFR, FEF_{25-75%} between different types of cooking fuels in India (LPG, kerosene and biomass fuel) and Thailand (LPG and biomass fuel).

7. Mean difference in exhaled breath CO levels in India.

8. Mean difference in exhaled breath CO levels for different types of areas (urban non-slum, urban slum and rural area) in India.

9. Mean difference in exhaled breath CO levels for different types of cooking fuels (LPG, kerosene and biomass fuel) in India.


11. Prevalence of symptoms/diseases between different areas in India (urban non-slum, urban slum and rural area) and Thailand (urban and rural area).

12. Prevalence of different symptoms/diseases between different types of cooking fuels in India (LPG, kerosene and biomass fuel) and Thailand (LPG and biomass fuel)

### 1.2.6 DEFINITION OF TERMS

The key terms of the topic of research are defined below:

#### 1.2.6 (a) Exposure to indoor air pollution

refers to the concentration in the immediate breathing environment over a specified time interval of indoor air pollution from the
combustion of biomass (wood, charcoal, crop residues, and dung) and coal as the primary source of domestic energy used for cooking and heating. In the present study, exposure to combustion of LPG, kerosene and biomass (wood and coal) is exposure to indoor air pollution.

1.2.6 (b) **Biomass fuel or biofuel** refers to any plant (wood, charcoal) or animal based material (dung, crop waste) deliberately burned by humans. In this study, biomass fuel is wood, coal, dung cakes and crop residues used in the two research areas from India and Thailand selected for investigation.

1.2.6 (c) **Respiratory health impact** refers to the respiratory diseases, which are caused by the indoor air pollutants, in relation to household energy use. The respiratory health impact in this study includes COPD (chronic obstructive pulmonary disease), asthma and other respiratory symptoms. Respiratory symptoms refer to symptoms caused by the indoor air pollution, for instance, cough, phlegm, wheezing/whistling, and breathlessness.

1.2.6 (d) **COPD: Chronic Obstructive Pulmonary Disease** refers to a lung disease characterized by chronic obstruction of lung airflow that interferes with normal breathing and is not fully reversible. The more familiar terms “chronic bronchitis” and “emphysema” are no longer used, but are now included within the COPD diagnosis. In this study the researcher used a validated respiratory health questionnaire from BOLD (Burden of Obstructive Lung Disease Initiative) and a post bronchodilator spirometry FEV₁/FVC < 70% to define COPD as the new GOLD (the Global Initiative for Chronic Obstructive Lung Disease) standard definition.
“Diagnosis of COPD is based on a history of exposure to risk factors and the presence of airflow limitation that is not fully reversible, with or without the presence of symptoms. A post-bronchodilator FEV₁/FVC <70% and a post-bronchodilator FEV₁ <80% predicted confirms the presence of airflow limitation that is not fully reversible.”

to define COPD.

1.2.6 (e) **Asthma** refers to a chronic airways disease characterized by recurrent attacks of breathlessness and wheeze, which varies in severity and frequency from person to person. Symptoms may occur several times during the day or week in affected individuals, and some people become worse during physical activity or at night. In the current study we used a validated questionnaire from ISAAC (International Study of Asthma and Allergic in Childhood) to define asthma.

1.2.6 (f) **Lung oxidative stress** refers to the presence of oxidative stress in the airways lung parenchyma either caused by exposure to indoor air pollutants or due to inflammatory changes in the lungs. In this study, breath exhaled carbon monoxide (eCO) was measured to determine the presence of lung oxidative stress. The lung epithelial cells produce CO in response to oxidative stress (caused by inhaling air pollutants), which can be measured in the exhaled breath. eCO is therefore a useful biomarker of lung oxidative stress in which concentrations in the normal range of 0 to 3 ppm. This study used breath exhaled carbon monoxide level more than 3 ppm to define lung oxidative stress.

1.2.6 (g) **Exhaled carbon monoxide (eCO)** refers to carbon monoxide (CO), which is excreted via expiration and it is a useful marker of underlying oxidative stress in the lungs.
1.2.6 (h) **Exhaled CO level** : refers to exhaled CO concentration which is measured by a hand-held eCO monitor (Vitalograph ®, UK) and it is sensitive to CO concentrations from 1 to 500 ppm (by volume).

1.2.6 (i) **Breath exhaled CO monitoring** refers to the measuring of the levels of carbon monoxide in exhaled breath. Breath exhaled CO monitoring is performed using the hand-held eCO monitor (Vitalograph ®, UK), the pocket sized eCO monitor, which is measured at a single time point. The subject measures breath CO levels in parts per million (ppm) by the subjects exhale fully, inhale deeply, and hold their breath for 20 seconds before exhaling rapidly into a disposable mouthpiece.

1.2.6 (j) **Breath exhaled CO monitor** refers to a device that is able to determine an approximate carboxyhemoglobin level (COHb), when used with a hand-held eCO monitor (Vitalograph ®, UK), portable Carbon Monoxide (CO) Analyzer.

1.2.6 (k) **Pulmonary Function Tests** refer to tests designed to measure how well the lungs are functioning. Spirometry, Body plethysmograpy and DLCO (Diffusing lung CO-efficient for CO) are the three important tools that measure airway patency, total lung capacity and diffusion capacity for gases respectively. A combination of these three tests constitutes Pulmonary Function Test.

1.2.6 (l) **Spirometry** refers to a test that measures airway patency and helps in the diagnosis of obstructive airways diseases such as asthma and COPD. Spirometry is the most common of the Pulmonary Function Tests (PFT), and specifically measures the amount (volume) and speed (flow) of air that can be inhaled and exhaled. The test is performed with a machine called a spirometer. In present study the researcher used the
EasyOne®, Switzerland and Microlab II®, UK spirometer. Both are ultrasonic flow-sensor based Spirometers, which measured the most important spirometric parameters including FEV₁, FVC, FEV₁/FVC, PEFR, FEF₂₅-₇₅%, FET and function by automatic interpretation with traffic light indication.

1.2.6 (m) FEV₁ (Forced Expiratory Volume in the first second) refers to the volume of air that can be forced out in one second after taking a deep breath, an important measure of lung function.

1.2.6 (n) FVC (Forced Vital Capacity) refers to the maximum gas volume which can be expired, as quickly and forcibly as possible, after a maximum inspiration.

1.2.6 (o) FEV₁/FVC ratio refers to the ratio of FEV₁ to FVC and tells the clinician what percentage of the total amount of air is exhaled from the lungs during the first second of forced exhalation.

1.2.6 (p) PEFR (Peak Expiratory Flow Rate) refers to a measurement of the amount of air that leaves the lungs on forced exhalation, which measures how fast a person can breath out (exhale) air.

1.2.6 (q) FEF₂₅-₇₅% or MMEF (Forced End-expiratory Flow or maximum mid-expiratory flow) refers to the mean forced expiratory flow during the middle half of the forced vital capacity (FVC) or the average expiratory flow over the middle half of the FVC. It should be taken from the blow with the largest sum of FEV₁ and FVC. FEF₂₅-₇₅% or MMEF is in use as an index of airway obstruction.

1.2.6 (r) Women refer to the women, who are more than 18 years old that live in households and reside in and around Pune district, India and Chiang Mai province, Thailand.
1.2.6 (s) **Urban non-slum areas** refer to geographical areas that constitute cities or towns, where are intensively developed areas except the areas that are called slum in the cities or towns. The minimum density requirement in each urban area is generally 400 persons per square kilometer. In present study, urban non-slum areas mean the areas, which are around University of Pune in Pune district, India and Muang district in Chiang Mai province, Thailand.

1.2.6 (t) **Urban slum areas** refer to the areas in a city or town, which are usually inhabited by the very poor or socially disadvantaged. Slums can be found in most large cities around the world. In the present study, urban slum areas mean only Yerawada slum in Pune district, India. Since, there are no slums in Chiang Mai province, Thailand, they are not defined.

1.2.6 (u) **Rural areas** refer to sparsely settled places away from the influence of large cities. Such areas are distinct from more intensively settled urban and suburban areas. Inhabitants live in villages, hamlets, on farms and in other isolated houses. In modern usage, rural areas can have an agricultural character. Lifestyles in rural areas are marked by limited services. Utilities like water, sewerage, street lighting, and public waste management are generally present in the larger settlements. Public transport is limited or absent. People usually use their own vehicles. But if this is impractical they may walk or ride an animal such as a horse, donkey, or camel depending on where they live. In the present study, urban slum areas mean Vadu village, which is around Pune district, India and Saraphi district in Chiang Mai province, Thailand.
There are 21 terms which are briefly defined. The four terms related to respiratory health are from the third term to the sixth term. The tests tools and markers are from term “g” – eleven terms. The last three terms define the areas chosen for the investigation and survey concerning the research problem. The first Chapter presents the background information in the first section and offers the preliminary details about the research topic in the second section of the first Chapter.