School of Public Health

The impact of domestic and school air quality on respiratory symptoms among primary school students with different socioeconomic backgrounds

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Declaration

This research was conducted in Western Australia. This thesis addresses the impact of domestic and school air quality on respiratory symptoms among primary school students from different socioeconomic backgrounds. The aim of the research was to evaluate the influence of socioeconomic status on respiratory symptoms and asthma among schoolchildren.

This thesis does not contain any material which has been presented for the award of any other degree or diploma in any university.

To the best of my knowledge and belief this thesis does not contain any materials previously published by any other person except where due acknowledgment has been made.

Signature:

Abstract

Respiratory symptoms including wheezing, tight chest, breathing difficulty, are common childhood disorders, and are the most important reasons for (National Health and Medical Research Council 1996; Rumchev, Spickett et al. 2002; Australian Centre for Asthma Monitoring 2005a)absenteeism in school age children that may decrease the quality of life (Lam, Chung et al. 1998; Penny, Murad et al. 2001). Although genetic background and environmental exposure seem to be the key factors for the development of respiratory symptoms, socio-economic status (SES) may also contribute to the development of those illnesses in children (Rona 2000). To investigate the extent to which socio-economic factors may contribute to the increased prevalence of respiratory symptoms and asthma in Australia we studied respiratory symptoms and asthma among primary school students from low and high socioeconomic backgrounds.

Objective: A cross sectional study to determine the impact of school and domestic indoor air pollution on respiratory symptoms among primary school students from different socio-economic backgrounds (low and high) was conducted within the Perth metropolitan area. The study was carried out in three stages: 1) Questionnaire survey, 2) Indoor air quality monitoring in schools, 3) Indoor air quality monitoring in houses.

Methods: We studied 104 primary school students from low and high socioeconomic areas of Perth metropolitan between 2007 and 2008. The respiratory symptoms and asthma were assessed with a standardized questionnaire. Schools and domestic environmental monitoring took place

in winter and summer in order to determine seasonal differences in concentrations of studied air pollutants. For this purpose 11 primary schools with low and high socio-economic backgrounds were selected. Domestic air qualities were monitored in 90 houses from each area of low and high socio-economic status. SES was derived from means of more than 2 indicators including education and income. The areas of low and high socio-economic status were also determined by the Australian Bureau of Statistics. Exposure levels to some primary indoor air contaminants including Volatile Organic Compounds (VOCs) ($\mu g/m^3$), formaldehyde (HCHO) ($\mu g/m^3$) and particulate matter with size 2.5 microns in diameter $PM_{2.5}$ ($\mu g/m^3$) and PM_{10} ($\mu g/m^3$) were measured in domestic and schools environments. Indoor temperature (TºC) and relative humidity (RH) (%) were also monitored. Multivariate analyses were then used to quantify the effect of relevant factors on the prevalence of respiratory symptoms.

Results

Socioeconomic status is a comprehensive index that refers to a broad range of factors, such as level of social communities, income, education, parental occupations and living conditions. School children from low socioeconomic groups showed more respiratory symptoms in this study. Those who had higher SES had fewer asthma and respiratory symptoms. We conclude that low socioeconomic status is itself a risk factor for respiratory symptoms and asthma among school children.

Conclusion

Asthma continues to impose a heavy burden on the nation's health care expenditures, Reduces productivity, and seriously affects the quality of life for individuals with asthma and their families.

Asthma is a public health problem that does not have a .quick fix. It will require the combined efforts of individuals with asthma and their families, health care providers, health care institutions, schools, workplace, governments, voluntary organizations, industry, and the general public.

Asthma and respiratory symptoms were more common in low socioeconomic status groups. There was no significant support for the hygiene hypothesis.

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This little is offered

to big people, who have

taught me

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Introduction

Respiratory disorders are the most important health problems in Australia (Australian Centre for Asthma Monitoring 2005a). The National Health and Medical Research Council (NHMRC 1996) estimated the cost of asthma for the community is between $585 and $720 million a year in Australia and (Bauman, Mitchell et al. 1992) have estimated that more than a fifth of Australian children with asthma report weekly wheeze and cough. Two-thirds of report school absences and one-third report frequent sleep disturbances due to asthma.

Statement of the problems

Respiratory and asthma symptoms are public health challenges in the area of children's health. Respiratory diseases can lead to life-threatening if not managed properly (Mendell and Heath 2005). Respiratory symptoms are the leading cause of school absenteeism in children, and result in missed workdays and lost productivity in adults as well (Mendell and Heath 2005). The evidence strongly suggests that poor indoor air quality in schools can impact on the respiratory health of children. According to Mendell and Heath (2005) children are at greater risk of the development of respiratory diseases in poor environmental conditions because their immune system is still developing. (Rumchev, Spickett et al. 2002; Rumchev, Spickett et al. 2004) have demonstrated that the exposure levels of indoor pollutants, such as Volatile Organic Compounds and formaldehyde are significant risk factors for asthma in children.

Even though poor indoor air quality (IAQ) may have a role in exacerbation of allergic disorders (California Air Resources Board 2005; Parker 2006 ; Parker 2006 ; California Air Resources Board 2005) the socio-economic status may also have a key role in the development and progress of respiratory symptoms and asthma, especially in school students (Weitzman, Sobol et al. 1990; Rona 2000; Basagaña, Sunyer et al. 2004). Basagana, Sunyer et al (2004) have shown that the influence of socio-economic status could be explained by current and past individual exposures to lifestyle and environmental factors.

Contrary to those beliefs the "hygiene theory" hypothesized that children who do not grow up with other siblings or animals in the house early in life have less developed immune systems due to less exposure to allergens and pollutants, resulting in less tolerance to irritants that may cause asthma. These types of concepts require to be answered and give rise to questions, such as: 1- Is there a difference in prevalence of respiratory symptoms among primary school students with different socio-economic background?

2- Is there a difference in exposure levels to VOCs, HCHO and particulate matter ($PM_{2.5}$), (PM_{10}) in houses located in areas with different SES?

3- Is there a difference in indoor air quality in houses with different house characteristics?

4- Is there an association between prevalence of respiratory symptoms in children and indoor air quality in schools and homes?

In summary, some researchers have shown links between exposure to allergens, pollutants and respiratory symptoms, while in contrast some other researchers have demonstrated that better hygiene and clean indoor environment may contribute to the increased prevalence of allergic diseases and respiratory symptoms. The present study will enhance our understanding and knowledge with regard to the two different hypotheses related to asthma and respiratory symptoms.

vi) - Significance of study

The study is significant for several reasons:

1- This is the first study to address the influence of SES on prevalence of respiratory symptoms among primary school students in Australia.

2- This study will assess the extent to which socio-economic factors and indoor air pollution will affect the prevalence of respiratory symptoms in school children.

3- This study will enhance our knowledge and understanding about the two contrasting theories; the hygiene theory and the theory that higher exposure to air pollutants and allergens is related to asthma and respiratory symptoms.

4- This study will summarize the preventive measures to reduce exposure to air pollution and allergens in school environments located in different SES and also efforts in improving indoor air quality of schools thus reducing the absenteeism and respiratory symptoms in students.

vii) - Aims of the study

Overall aim

The aim of the study is to investigate the associations between socio-economic status, indoor air quality in houses and schools and the prevalence of respiratory symptoms among Australian primary school children.

viii) Objectives of the study

- To investigate the association of socio-economic status with prevalence of respiratory symptoms among primary school students.
- To determine the home and environmental factors that could affect indoor air quality.
- To determine the indoor air levels of Volatile Organic Compounds (VOCs) ($\mu g/m^3$), formaldehyde (HCHO) ($\mu g/m^3$) and Particulate Matter with size 2.5 and 10 microns in diameter ($PM_{2.5}$) ($\mu g/m^3$) and (PM_{10}) ($\mu g/m^3$), respectively, in schools and domestics located in areas with low, medium and high socio-economic status.
- 4- To investigate the association between home and school characteristics and indoor air quality on respiratory health status.
- 5- To recommend strategies to reduce the prevalence of respiratory disorders.

ix) - Benefits of the study

The outcome of this study should be very beneficial for studies in the future to further investigate the impact of socioeconomic status on prevalence and incidence of asthma and respiratory symptoms in Australia. Indeed, National Health and Medical Research Council, Department of Education, city councils, Department of Health and Age Care and Department of Infrastructure and Planning can use this project's result for implementation of their strategic and infrastructural planning for reduction of asthma occurrence.

x) - Limitations of the study

In this study, we acknowledge limitations of sample size and instruments.

The first limitation was sample size, especially with medium socioeconomic participants, who have not taken part in the child health questionnaire and environmental assessment. To achieve the aims of study, rather than three groups (low, medium and high) two groups of schoolchildren classified as low and high socioeconomic status were determined to participate in this research project.

The second limitation of study was the uncompleted questionnaires. The uncompleted questionnaires were well defined and participants were contacted and reminded about the study and asked if they would like to take part in the study and complete the questionnaire. Those general limitations were overcome by making direct contacts with principals, staff and guardians before and during the project and encouraged them to cooperate with the study through describing the benefits of research.

Another limitation was related to technical problems of the equipment used to obtain measurements which affected the duration of this study. For example power off, manipulation of equipment and damaged laboratory equipment were main components of our technical problems. To achieve the purpose of investigating all field equipment were replaced with new batteries before sampling times. Additionally, staff and students instruction guidline before and during sampling times has provided us the main goals of environmental measurement accurately. The laboratory of school of public health has supplied new pieces to replace them with the damaged pieces of chemical analyzing equipment.

In brief, the project of “The impact of domestic and school air quality on respiratory symptoms among primary school students with different socioeconomic backgrounds” was exposed to some limitations.

- Sample size limitation.
- Participants’ propensity to take part in environmental monitoring stages.
- Uncompleted questions about income and the family’s educational levels.
- Technical problems before, during and after environmental assessment and also chemical analysis with tools and instruments.

Chapter one

1. Air pollution

An air pollutant is a substance in the air that can cause harm to humans and the environment (de Hollander, Melse et al. 1999; W.H.O 2007). Pollutants can be in the form of solid particles, liquid droplets, or gases. In addition, they may be natural or man-made (de Hollander, Melse et al. 1999; EPA-U.S. Environmental Protection Agency 2009). Research has demonstrated that the indoor pollutants since the 1950 ^{s} has been changed by the personal habits of residences, life style and new products used in buildings which emit chemicals including solvents, un-reacted monomers, and additives (Weschler 2009).

Epidemiological studies have shown that exposure to air pollutants is associated with adverse health effects (Brooks and Davis 1992). The World Health Organization states that “2.4 million people die each year from causes directly attributable to air pollution, with 1.5 million of these deaths attributable to indoor air pollution” (W.H.O 2007). However, air quality is an important component of a healthy environment. It provides a favourable environment for health, productivity, sense of comfort and well-being (Brooks and Davis 1992 ; W.H.O 2007).

The impact of air pollutants on health was identified by the Egyptians as far back as 1500 BC. They knew that being exposed to silica dust produced by cutting stones caused respiratory diseases (Brooks and Davis 1992). Our understanding of the health concern of air pollution has taken centuries to develop. Hippocrates of Cos (c.460-374 BC) stressed that air in mines, and in the environment produced adverse health effects (Brooks and Davis 1992). By the 13^{th} century, air pollution due to coal combustion emissions was feared as a source of illness and death. However, it was not until the 17^{th} Century that serious discussion of the association between air quality and diseases began to emerge (Brooks and Davis 1992).

Even with this comprehensive historical information, no serious efforts have been made to improve air quality in these last few decades (Brooks and Davis 1992). Investigations have established that exposure to air pollution had always been the main cause of dramatic disasters of illnesses and death in different locations, for instance in the Meuse valley, Belgium in 1930, Donora, Pennsylvania in 1948, London, England in 1952, Union carbide – India (Halbwache, Sabroux et al. 2004). In addition, the Lake Nyos Tragedy, Aug. 21.1986, and 1,800 asphyxiation deaths from sudden release of CO2 from cold deep waters of Crater Lake over the “extinct” volcano are also other places demonstrate the detrimental impact of air pollutants on nature (Brooks and Davis 1992; Halbwache, Sabroux et al. 2004). With consideration to this broad threat to general population health and a healthy environment, many efforts have appeared to reduce levels of air pollutants. In the U.S., Clean Air Legislation of 1955 launched federal air pollution regulations (Brooks and Davis 1992). This vital reaction was followed by the 1963 Clean Air Act, the Air Quality Act of 1967, and the 1970, 1977 and 1990 Clean Air Act Amendments (Brooks and Davis 1992). The U.S. Environmental Protection Agency (EPA) conducted a considerable amount of research on the chemical constituents of ambient air and has published a four part list of hazardous organic chemicals commonly found in ambient air (Brooks and Davis 1992).

Since the early 1970s, the health effects of indoor air pollution have been investigated with increasing intensity on diverse aspects of indoor air pollution, sources, concentrations and health effects (Samet, Marbury et al. 1987). The National Institute of Occupational Safety and Health released its first Indoor Air Quality (IAQ) investigation in 1971 (Brooks and Davis 1992).

Consequently, new concepts in the understanding and the drawing up of protective legislation toward indoor air pollution and potential health effects have begun. Investigations have found many pollutants in indoor air that will probably be with different potential for chronic diseases and health effects.

2. The importance of indoor air quality

All of us face a variety of risks to our health as we go about our day-to-day lives. Driving in cars, flying in planes, engaging in recreational activities, and being exposed to environmental pollutants all pose varying degrees of risk. It has been shown that adults spend an average of 87 percent of their time indoors (Chapin 1974; de Hollander, Melse et al. 1999; California Air Resources Board 2005; California Air Resources Board 2005) and children under 12 years of age spend about 86 percent of their time indoors (California Air Resources Board 2005). It is estimated that children spend about 21 percent of their time in school or probably stay in a school setting for up to 10 hours per day (Leickly 2003). They spend at least 1,100 hours per year at school (Leickly 2003). Social research has shown that working adults spend about 25 percent of their time at other indoor locations rather than homes, such as office buildings, stores, and restaurants, primarily for work (Leickly 2003). In addition, Leickly (2003) has indicated that older people spend a great deal of time in their homes. It has been estimated that the Australian general population spends more than 90 percent of their time indoors, such as homes, schools, offices and public buildings (Australian National Asthma Council 2004). In the past several years, a growing body of scientific evidence has suggested that the air due to different compositions within homes and other buildings can be a more important health concern than the outdoor air (WHO-Department of Public Health & Environnment 2007; U.S. EPA Office of Air and Radiation 2007). It has been concluded that people spend the majority of their time indoors for that reason, for many people the risks to their health may be greater due to exposure to air pollution indoors than to air pollution outdoors (Brooks and Davis 1992). It has also been found that pollutants emitted indoors have a 1000-fold greater chance of being inhaled than do those emitted outdoors (California Air Resources Board 2005).

To explore indoor pollutants, health effects investigators have revealed that numerous chemical and biological agents contribute to indoor air pollution.

Brook and Davis (1992) have counted more than 900 chemical and biological agents contributing to the air pollution and these are still growing in numbers. There is body of research (Maroni, Seifert et al. 1995; Rumchev 2001; Rumchev, Spickett et al. 2002; Zhang 2004) which has discussed the impact of indoor air pollution on respiratory health. Research indicates different effects of air pollutants on respiratory systems, such as increased mortality and incidence of lung cancer, increased frequency of symptomatic asthma attacks, and increased incidence of lower respiratory tract infections and exacerbation of chronic cardiopulmonary or other diseases. In addition, exposure to pollutants can increase the rate of hospitalisation, physician visits and medication, decreased pulmonary function, and reduction of FEV1 or FVC associated with clinical symptoms (Official statement of the American Thoracic Society 2000). Furthermore, field research addresses more effects of air pollutants on upper and lower respiratory systems, for example, increased prevalence of wheezing unrelated to colds or wheezing on most days or nights, increased prevalence or incidence of chest tightness and increased prevalence or incidence of cough / phlegm production requiring medical attention (Official statement of the American Thoracic Society 2000). Environmental Protection Agency Office of Air and Radiation (20007) has demonstrated air quality can change any time from day to day or even hour to hour with direct effects on our life quality. In addition, the U.S.EPA Office of Air and Radiation (2007) has reported that people who may be exposed to indoor air pollutants for long periods of time are often those most susceptible to the effects of indoor air pollution. Based on this report, these groups include the young, the elderly, and the chronically ill, especially those suffering from respiratory or cardiovascular disease.

In conclusion, we could say indoor air quality is a critical health concern, especially for young children, since young children's respiratory and immune systems are still developing. Secondly, they spend most of their time indoors.

3. Sources of indoor air pollution

The sources of indoor air pollution are different. Brook and Davis (1992) efforts explored various sources of indoor air pollution such as oil, gas, kerosene, coal, wood, and tobacco products, building materials, asbestos containing insulation, wet or damp carpets and cabinetry or furniture made of certain pressed wood products, products for household cleaning and maintenance. Researchers have concluded households release pollutants more or less continuously (Brooks and Davis 1992). This finding is consistent with U.S Environmental Protection Agency (1995) investigations, which have revealed that personal care, hobbies, central heating, cooling systems and humidification devices can be considered indoor air pollution sources. It is identified that poor design installation and maintenance of heating are able to provide combustion emission and bio-aerosols in to the indoor environment (Brooks and Davis 1992).

There is a body of research (Brooks and Davis 1992; Shineldecker 1992; Maroni, Seifert et al. 1995) which suggests that human activities are causing air and environmental pollution, which can have effects on human health.

Additionally, some studies have indicated that emissions and particles from building materials, furnishing, appliances , office equipment, residential equipment, domestic cleaning materials, human activities and transient materials as other sources of indoor air pollutions (Brooks and Davis 1992; Maroni, Seifert et al. 1995). The U.S Environmental Protection Agency (1995) has shown that in some cases factors such as setting and maintenance are significant factors for pollution emission. For example, carbon monoxide can be emitted at higher levels from an improperly adjusted gas stove than from one that is properly adjusted (EPA 1995; EPA 1995). Other sources related to activities carried out in homes release pollutants occasionally (EPA 1995). These include smoking, the use of malfunctioning stoves, furnaces, or space heaters, the use of solvents in cleaning and hobby activities, the use of paint strippers in redecorating activities and the use of cleaning products and pesticides in housekeeping (EPA 1995), which may remain in the air for long periods of time (EPA 1995).

4. What are the most important air pollutants?

Comprehensive investigations have established a variety of sources of the indoor air pollutants. Indoor air contaminations were classified in various ways. A simple classification and typical examples of them are combustion products, volatile chemicals and chemical mixtures, respirable particulates, respiratory products, bio aerosols, radio nuclides and odors (Brooks and Davis 1992). Extensive evidence has suggested that outdoor pollutants could enter all types of buildings and transport (Brooks and Davis 1992; Maroni, Seifert et al. 1995). Indoor ventilation systems are considered to be of major concern toward the indoor pollutants concentrations levels if they work inadequately (Brook and Davis 1992 ; Maroni, Seifert et al. 1995). Furthermore, the level of indoor air pollution depends on the level of outdoor pollution, the level and type of ventilation used, and the nature of pollutant losses to indoor surfaces (Brook and Davis 1992 ; Maroni, Seifert et al. 1995; Pennsylvania Department of Health Bureau of Epidemiology 2002).

4.1 Volatile organic compounds (VOCs) and Formaldehyde (HCHO)

Recently, using new technology products and materials has raised concern about the level of concentration in air pollutants, particularly the volatile organic compounds (VOCs), which are a big risk factor towards human health (Brooks and Davis 1992; Molhave, Clausen et al. 1997; Pennsylvania Department of Health Bureau of Epidemiology 2002; The Minnesota Department of Health Indoor Air Unit 2007).

Volatile Organic Compounds (VOCs) are a wide spectrum of chemicals that evaporate easily at room temperature (Maroni, Seifert et al. 1995; Rumchev, Spickett et al. 2004; EPA-U.S. Environmental Protection Agency 2009; EPA 2009). The term “organic” indicates the presence of carbon containing chemicals (Brook and Davis 1992 ; Maroni, Seifert et al. 1995). There are thousands of different VOCs produced and used in our daily lives. Some examples are: benzene, toluene, methylene chloride, formaldehyde, xylene, ethylene glycol, 1, 3-butadiene, (Brook and Davis 1992 ; Maroni, Seifert et al. 1995; The Minnesota Department of Health Indoor Air Unit 2007). VOCs have been associated with certain short term and long-term adverse effects on biological organs (Brooks and Davis 1992; Molhave, Clausen et al. 1997). Some researchers have reported that Microbial Volatile Organic Compounds are a number of factors that are associated with mucous symptoms; irritation of the eyes, nose, airway, or coughing (Araki, Kawai et al. 2010).

Probably the material most used in numerous manufacturing processes and building materials is formaldehyde (Brooks and Davis 1992; Rumchev, Spickett et al. 2002). The smoke from cigarettes, fuels and urea-formaldehyde resins (used in large quantities as glues in the manufacturing of wooden products such as particle board and plywood) have also been indicated as other sources of formaldehyde (Maroni, Seifert et al. 1995). Consequently, it is accepted that formaldehyde is the most recognized indoor VOC (Brooks and Davis 1992; Maroni, Seifert et al. 1995; Rumchev, Spickett et al. 2004). Formaldehyde is the simplest aldehyde, a colorless gas at normal room temperature, water soluble and readily photo-oxidized in sunlight to carbon dioxide (Brooks and Davis 1992; Maroni, Seifert et al. 1995). Furthermore, a growing body of scientific evidence has indicated that the exposure levels to indoor pollutants, such as Volatile Organic Compounds and formaldehyde are significant risk factors for asthma in children (Rumchev 2001; Rumchev, Spickett et al. 2002; Zhang 2004).

4.2 Particulate matter (PM)

Particulate matter (PM) is one of the important indoor air pollutants, comprising a mixture of particles. They can be solid, liquid or both, suspended in the air and representing a complex mixture of organic and inorganic substances (Maroni, Seifert et al. 1995; World Health Organization Europe 2005). “Airborne particles have irregular shapes, and their aerodynamic behavior is expressed in terms of the diameter of an idealized spherical particle known as aerodynamic diameter” (U.S.EPA 2010). We can summaries particulate matter (PM) properties according to their aerodynamic diameter which is related to particle size (World Health Organization Europe 2005). Particulate matter varies in size, composition and origin, and is easily able to enter our respiratory system to transfer itself using the circulatory system in the form of inhalable sized particles into the different organs in our body (National Institute for Occupational Safety and Health 2009). Some research has indicated that the toxicity of larger particles with the same chemical composition are significantly less than ultrafine or nano particles (Duffin, Tran et al. 2002 ; Barlow, Clouter-Baker et al. 2005). Field research has explored how the size and specific chemical composition of particulate matter are the most relevant factors in determining the respiratory reaction (Chunglin, Jencchen et al. 2005). These authors indicate that increased size may lead to increased risk of asthma in humans. This is consistent with the study of Cheng Fang, Shen Wu et al (2006), which has indicated that the size of particulate matter is the most relevant factor affecting human respiratory health.

The size of the particles also determines the time they spend in the atmosphere (World Health Organization Europe 2005). While sedimentation and precipitation removes PM_{10} from the atmosphere within few hours of emission, particles with a size of 2.5 μm in diameter may remain there for days or even weeks (World Health Organization Europe 2005). These particles can be transported over long distances (World Health Organization Europe 2005). Particles with an aerodynamic diameter smaller than 10 μm may reach the upper part of the airways and lung (World Health Organization Europe 2005). However, smaller or fine particles with an aerodynamic diameter smaller than 2.5 μm are more harmful because they penetrate more deeply into the lung and may reach the alveolar region (World Health Organization Europe 2005). The major PM components are sulphate, nitrates, ammonia, sodium chloride, carbon, mineral dust and water (World Health Organization Europe 2005). Particles may be classified as primary or secondary, depending on their formation mechanism (World Health Organization Europe 2005). Primary particles are directly emitted into the atmosphere through human activities (anthropogenic) and natural processes (World Health Organization Europe 2005). According to World Health Organization Europe (2005), anthropogenic processes include combustion from car engines (both diesel and petrol), solid-fuel (coal, lignite and biomass) combustion in households, industrial activities (building, mining, manufacturing of cement, ceramic and bricks, and smelting), and erosion of the pavement by road traffic and abrasion of brakes and tires. The World Health Organization Europe (2005) has also indicated that secondary particles are formed in the air, usually by chemical reactions of gaseous pollutants.

4.3 Environmental tobacco smoke (ETS)

Smoking is one of the most detrimental human social behaviors with significant effects on health conditions. Brooks and Davis (1992) have stated how the quality of indoor air is dramatically affected by human actions and habits. Wide-ranging research has revealed that environmental tobacco smoke is the mixture of smoke that comes from the burning end of a cigarette, pipe, or cigar and smoke exhaled by the smoker (U.S. Environmental Protection Agency 1995). It contains a complex mixture of over 4,000 compounds, more than 40 carcinogenic agents these to induce cancer in humans or animals. Many of these are strong respiratory irritants. ETS is often referred to us "passive smoke" (U.S. Environmental Protection Agency 1995). Some researchers have found that there are a number of factors that are associated with exacerbation of asthma, such as air pollution, environmental tobacco smoke, allergenic respiratory infections, living in an urban environment and lower socioeconomic class (Gergen, Mortimer et al. 1999; Aligne, Auinger et al. 2000; Fauroux, Sampil et al. 2000; Bardana 2001; D'Amato, Liccardi et al. 2002). Asthmatic children are especially at risk of second hand smoking, which may increase the number of episodes and severity of symptoms in hundreds of thousands of asthmatic children, and also may cause thousands of non-asthmatic children to develop the disease each year (U.S. Environmental Protection Agency 1995). In United States of America, ETS is responsible for approximately 3,000 lung cancer deaths each year in non-smoking adults and impairs the respiratory health of hundreds of thousands of children (U.S. Environmental Protection Agency 1995). Further investigation by EPA (1995) revealed that infants and young children whose parents smoke in their presence are at increased risk of lower respiratory tract infections (pneumonia and bronchitis) and are more likely to have symptoms of respiratory irritation like coughs, excess phlegm, and wheezes. Also, the EPA (1995) estimated that passive smoking annually causes between 150,000 and 300,000 lower respiratory tract infections in infants and children fewer than 18 months of age, resulting in between 7,500 and 15,000 hospitalizations each year in the USA. These children may also have a build-up of fluid in the middle ear, which can lead to ear infections.

Tobacco smoking indoors also increases airborne levels of carbon monoxide and other substances such as nicotine, polycyclic aromatic hydrocarbons, acrolein, nitrogen dioxide and respirable particulates (Brooks and Davis 1992).

5. Outdoor air quality

The most pivotal and effective source of human health, which may directly or indirectly be able to affect the respiratory system of many people is air quality. Air pollutants are known or suspected agents in the air that cause adverse health effects. The outdoor air is also called ambient air (New South Wales Government- Department of Health 2009). Ambient air could be polluted by a single point source or, more often, generated from different diffuse sources, for example traffic and power generation (World Health Organization 2000). Furthermore, pollutants are able to be transported long distances to contribute further to air pollution (World Health Organization 2000).

To understand ambient air pollutant sources, comprehensive researches have been done. It has been established that human activities contribute detrimental effects on air quality (World Health Organization 2000). Fisher et al (2002) have demonstrated in both urban Australia and New Zealand that the main sources of air pollution are motor vehicle emissions. Bushfires are another major source of air pollution in some parts of Australia (Fisher, Rolfe et al. 2002). The Australian National Asthma Council (2004) has suggested particulate matter with diameters of up to 10 microns, ozone, carbon monoxide nitrogen dioxide and lead could be considered as major groups of ambient air pollutants. This report is consistent with other research, which has suggested that major pollutants, such as sulfur oxides, nitrogen oxides, carbon monoxide, carbon dioxide, volatile organic compounds, particulate matter, ammonia odors and ground compounds level ozone are produced by human activities (Brooks and Davis 1992; Shineldecker 1992). These pollutants can be emitted from different sources, for instance tobacco smoking, wood-based panels, furniture's, glues, dyes, permanent-press clothes, markers, paints and cigarettes (Brooks and Davis 1992; Shineldecker 1992).

It has been suggested that air pollution is the cause of 2.3% of all deaths in Australia. Air pollution has also been estimated as causing 640 to 1400 premature deaths and almost 2000 yearly hospitalisations in metropolitan areas such as Sydney (New South Wales Government 2009). The health costs of air pollution in New South Wales is estimated at around $4.7 billion dollars yearly (New South Wales Government 2009). In New Zealand, an estimated 900 deaths per year are attributable to air pollution (2% of all deaths), of which nearly half are due to motor vehicle emissions (Fisher, Rolfe et al. 2002).

The reaction of the human body to exposed pollutants depends on multiple factors, for instance, type of pollutant, degree of exposure, individual's health status and genetics (New South Wales Government 2009). The respiratory effects of air pollutants beyond exposure may be in the form of severe or chronic, subtle or obvious symptoms such as difficulty breathing, wheezing, coughing, asthma, bronchitis and magnification of existing respiratory or other health conditions (World Health Organization 2000).

6. Indoor air quality at schools

The general population considers that outdoor air quality is more important than indoor air, probably many of them are not aware that the indoor levels of pollutants have a greater effect on health and abilities of occupants. The health effects of indoor air quality at school is of significant concern because children spend about 21 percent of their time in school (Leickly 2003). In addition, children of school age still have a developing physiology (Australian National Asthma Council 2004; Mendell and Heath 2005). They consume more energy, and have a higher level of metabolism and faster respiration rate (Pennsylvania Department of Health Bureau of Epidemiology 2002). Therefore, exposure to indoor air pollutants in classroom during long and short terms is a serious health risk.

To determine the health effects of indoor air at schools, comprehensive field research has shown that the quality of indoor air is associated with respiratory problems in schools in America and European countries (Tortolero, Bartholomew et al. 2002). The Australian National Asthma Council (2004) has indicated poor indoor air quality at schools is related to students' health conditions and learning ability and to staff health and performances.

The first priority to decrease air pollutants level is controlling the source. If pollutant sources are not controlled, indoor air problems can develop even if the Heating, Ventilation, and Air-Conditioning (HVAC) system is properly designed and maintained (Pennsylvania Department of Health Bureau of Epidemiology 2002). In addition, indoor air pollutants may originate within the school building or be drawn in from the outdoors. In Australia, studies have indicated an association between indoor air pollution and respiratory symptoms between school students (Rumchev 2001; Rumchev, Spickett et al. 2002; Rumchev, Spickett et al. 2004; Zhang 2004). Indoor air contaminants with diverse sources may consist of particles, dust, fibers, biological agents and gases or vapors (Brooks and Davis 1992; Pennsylvania Department of Health Bureau of Epidemiology 2002).

Epidemiologic research has indicated the levels of air pollutants can vary by time and location within the school building, or possibly within a single classroom (Pennsylvania Department of Health Bureau of Epidemiology 2002). Comprehensive environmental data from 385 classrooms in 60 elementary schools in Southeast Texas have determined that the levels of many pollutants and allergens in the school environments were high (Tortolero, Bartholomew et al. 2002). Data from Europe has revealed that schools in European countries frequently had serious indoor environmental quality problems including high levels of Volatile Organic Compounds (VOCs), such as benzene, toluene, styrene and allergens, due to poor building construction, maintenance, cleaning and ventilation (Carrer, Bruinen et al. 2002). This is consistent with the Boston studies, which have shown serious indoor air quality problems related to ventilation, maintenance, and cleaning deficiencies (Anderson, Anis et al. 2002). The evidence strongly suggests that poor indoor air quality in schools can affect the respiratory health of children.

Consequently, indoor air pollutants at school contribute to low performance and learning ability in schoolchildren. Air pollutants with different size in diameters are able to be inhaled to demonstrate extensive symptoms of diseases.

7. Understanding the respiratory system

The respiratory system consists of a pair of lungs within the thoracic cage. The right lung is divided by transverse and oblique fissures into three lobes: upper, middle and lower. The left lung has an oblique fissure and two lobes.

Each lobe is divided into a number of wedge-shaped bronco pulmonary segments with their apices (Ward, Ward et al. 2006).

7.1. Function of the respiratory system

The purpose of the lungs is to get oxygen into the body and get carbon dioxide, a waste gas, out".

7.1.1. Upper Airway

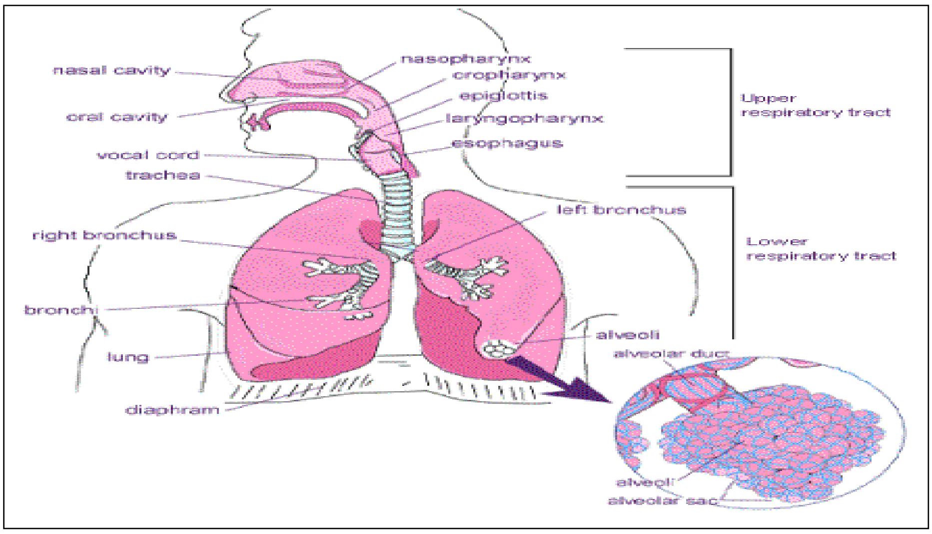
According to Ward et al (2006) the upper respiratory tract consists of the nose, pharynx and larynx. The upper airway works to move warmed and moistened air as it enters the nose after filtering dust air to the lower airway.

7.1.2. Lower airway

The lower respiratory tract starts with the trachea at the lower border of the cricoids cartilage. It bifurcates into right and left main bronchi. The right main bronchus is wider, shorter and more vertical than the left, so inhaled foreign bodies enter it more easily (Ward, Ward et al. 2006)

The airways divide repeatedly to generate bronchioles and terminal bronchioles which lead to respiratory bronchioles, the first generation to have alveoli. These lead to alveolar ducts and alveolar sacs. The airways from trachea to respiratory bronchioles are lined with ciliated columnar epithelial cells, Goblet cells and sub mucosal glands secrete mucus (Ward, Ward et al. 2006). Lymph channels are absent in alveolar walls, but accompany small blood vessels conveying lymph towards the hilar bronchopulmonary nodes and from there to tracheobronchial nodes.

The anatomical architectures of upper and lower respiratory system



Figures (I) modified from: ***Ohio State University Medical Center (2007), USA***

8. Respiratory symptoms and asthma definition and recognition

Respiratory symptoms including wheezing, tight chest, breathing difficulty, are common childhood disorders (Lam, Chung et al. 1998) and are the most important reasons for absenteeism in school age children that may decrease the quality of life (Lam, Chung et al. 1998; Penny, Murad et al. 2001; California Air Resources Board 2005). Indoor allergens and irritants can play a significant role in triggering respiratory attacks (EPA 2009). Common triggers of respiratory symptoms and asthma are still unknown, but may include environmental tobacco smoke, air pollution, weather, social status and biological contaminations such as mould, pollen, dander's from animals, and viral infections (Kim, Smorodinsky et al. 2004; Claudio, Stingone et al. 2006). Investigators have shown that respiratory symptoms are the leading cause of school absenteeism in children, and result in missed workdays and lost productivity in adults as well (Mendell and Heath 2005).

Asthma is a complex syndrome (Von Mutius 2009) with many clinical phenotypes in both adults and children. Busee and Lemanske (2001) have suggested that for many patients the disease has its roots in infancy and both genetic factors (atopy) and environmental factors, viruses, allergens, and occupational exposures.

Asthma is likely a syndrome rather than one disease entity, in which different pathways eventually result in various phenotypes of variable airway obstruction (Von Mutius 2009). Asthma is a chronic inflammatory disease with symptoms including reversible airway constriction, chest tightness, cough, and wheezing.

Although asthma develops most commonly in children, recent data suggest increases in new cases among adults and the elderly (Tinkle 2005). Conversely, there are still many un- answered questions regarding etiology of asthma which needed to be answered.

9. Epidemiology of childhood asthma and respiratory symptoms

Epidemiology may be viewed as based on two fundamental assumptions: first, that human disease does not occur at random and, second, that human disease has causal and preventive factors that can be identified through systematic investigation of different populations. In epidemiological investigations, the pivotal keys toward diseases distribution measurement are prevalence and incidence rates.

The rate of current cases in a study population during a specified period of time is known as prevalence and incidence rate refers to the rate of the number of new cases to the population at risk during a specified time (Rumchev 2001). A cross-sectional study is a descriptive study in which diseases and exposure conditions are measured simultaneously in a given population (Lilienfeld and Stolley 1994; Rumchev 2001).

Strachan (2000) has indicated that some limitations in cross-sectional studies can affect the study result. For example, parental recall and missed reporting first episodes of asthma as chest infection.

9.1. Prevalence of asthma and respiratory symptoms in children worldwide

The phase III of the International Study of Asthma and Allergies in Childhood has demonstrated that the prevalence of wheeze in the last 12 months among those aged 6–7 years ranged from 2.4% to 37.6% and was highest among centers in New Zealand, the United Kingdom, Australia and Latin America (Pearce, Aït-Khaled et al. 2007). Investigators in CDC (2004) have estimated that 21 million people in the United States currently have asthma; within this population, 11.8 million Americans (4.2 million children under 18 years of age) had an asthma episode or attack during the same year. In addition, fourteen million missed school days and 14.5 million missed workdays annually have been attributed to asthma. CDC (2004) has estimated that the annual direct health care cost attributable to asthma is estimated to be approximately $11.5 billion. Some of the indirect costs of asthma include absence from work and school, activity limitations, sleep disturbances, and death(CDC 2004). Some studies have indicated the cost of the effects of pollutants on health, such as anxiety, pain, suffering, and decreased potential resulting from school absenteeism are more difficult to measure (Weiss and Sullivan 2001; Wu and Takaro 2007). Also they indicated that the indirect costs (e.g., lost productivity) were approximately $4.6 billion, for a total of $16.1 billion dollars(American Lung Association 2005).

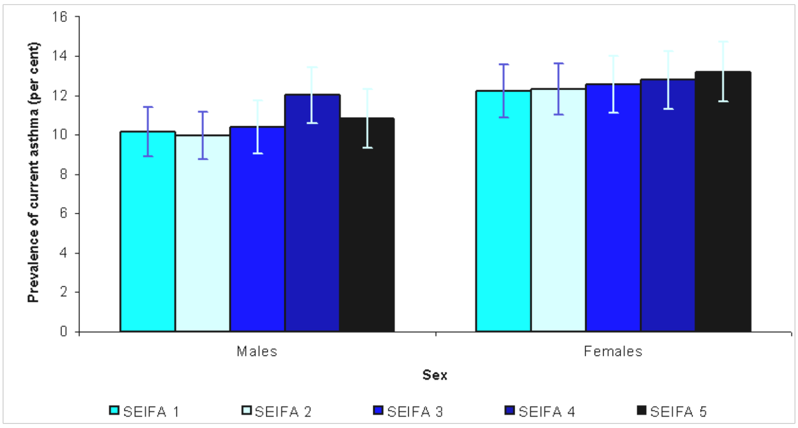
9.2. Prevalence of asthma and respiratory symptoms in Australian children

Pervious study by Australian Centre for Asthma Monitoring (2005) revealed that asthma has become a growing public health concern in Australia. In addition, they estimated that asthma affects 14–16% of children and 10–12% of adults, which are high rates by international standards. The prevalence of asthma in Australia increased through the 1980s and 1990s, but evidence suggests there has been no further increase in recent years (Australian Centre for Asthma Monitoring 2005a). The above report also mentioned that the recent nationwide survey, which has conducted in 2004–05, estimated that 11.3% of children aged 0–15 years in Australia had current asthma. It has also been estimated that the prevalence of current asthma in adults in recent years has ranged from 9.9% to 15.1% with most estimates around 11% (Australian Centre for Asthma Monitoring 2008). In

2006, almost 4 million Australians (20% of the total population) were children aged less than 15 years. Of these, 2.0 million were boys and 1.9 million were girls. In 2005–06, there were 536,978 hospitalisations among children this was 7% of all hospitalisations (Australian Centre for Asthma Monitoring 2008). Hospitalisation rates were higher for boys than girls (14,807 compared with 11,478 hospitalisations per 100,000 children, respectively), the most common reason for hospitalisation among children overall was for respiratory conditions (17%) (Australian Centre for Asthma Monitoring 2008). Based on Australian Centre for Asthma monitoring (2008), the risk of dying from asthma is highest in the elderly. It has been concluded that in primary school-aged children, asthma is more common among boys than among girls (Australian Centre for Asthma Monitoring 2005). The prevalence of asthma in children aged 2 to 15 years in Western Australia (2004), New South Wales (2001), and South Australia (2003-04) was estimated as 14.6%, 15.7% and 18.4%, respectively(Australian Centre for Asthma Monitoring 2005). Asthma self-reported and defined by 'yes' responses to 'have you ever been told by a doctor or a nurse that you have asthma?' and 'do you still get asthma?' Figures (II) shows Prevalence of asthma in Australian children 2003.

(SEIFA-* Socio-Economic Indexes for Areas (SEIFA) is a product developed especially for those interested in the assessment of the welfare of Australian communities)

Asthma in Australia 2003



Figures (II) *modified from: Australian Centre for Asthma Monitoring 2003, AIHW Asthma Series 1. AIHW Cat. No. ACM 1, Canberra: AIHW*

(Bauman, Mitchell et al. 1992 Jun) have estimated that more than one-fifth of Australian children with asthma report weekly wheeze and cough, two-thirds report school absences, and one-third report frequent sleep disturbances due to asthma. The proportion of total health expenditure during the financial year 2000-01 attributed to asthma care was highest among children; particularly boys aged 5–14 years, where it was 5.5% of annual health expenditure in that age group. Per capita asthma expenditure was highest for children aged 0–4 years, in which, on average, $76 was spent per boy and $66 per girl (Australian Centre for Asthma Monitoring 2005). Furthermore, a cohort study by (Kenny, Lancsar et al. 2005) indicated that the median cost of asthma among asthmatic people is $89 per person per year (range $0 to $4,882). The median costs included $8 for services and $40 for medications and asthma related equipment. However, it has been reported (Australian Centre for Asthma Monitoring 2008) that the prevalence of recent wheeze had decreased by 0.8% per year between phase I (conducted in 1993) and phase III (2002) in Australia. Australian Centre for Asthma Monitoring (2008) recently reported in Singapore (–0.80% per year) and South Korea (–1.71% per year in Seoul the prevalence of recent wheeze between phase I and III, declined but increases were observed in the eastern Mediterranean region (0.79% per year), Spain, the United Kingdom (0.50%) and Canada (0.47%). Furthermore this report has indicated that the prevalence of asthma in English-speaking countries decreased.

Chapter Two

The socio economic status and health

Introduction

The effects of socio economic status on human health go beyond the physical, biological, behavioral, and environmental causes of disease to embrace the relationships between health and social context (Poureslami, MacLean et al. 2004). Many efforts have been made to describe the socio economic status index, which contains a broad range of factors, such as level of social standing, income, education, and living conditions (Adler, Boyce et al. 1994; Ostrov and Adler 1998 ; Adler and Ostrov 1999; Dales, Choi et al. 2002 ; Pallasaho, Lindström et al. 2004). The National Health Survey in Australia 2004-5 (ABS 2006) has illustrated that people with lower socio economic status are more exposed to smoke and various unfavorable social conditions. They are less active and less likely to be involved in sport, and they are more likely to be obese or overweight. They have less access to a vegetable, fruit intensive diet (ABS 2006). These are risk factors for a number of long-term health conditions, such as respiratory diseases, lung cancer and cardiovascular diseases (Gergen, Mortimer et al. 1999; Aligne, Auinger et al. 2000; Fauroux, Sampil et al. 2000; Bardana 2001; D'Amato, Liccardi et al. 2002).

Families from low socioeconomic status often lack the financial, social, and educational supports that characterize families with high socioeconomic status. Poor families may also have inadequate or limited access to community resources that promote and support children's health. Charles Miller and Salkind (2002) have assumed that socio economic status begins to affect health through parental environment, such as exposure to toxins and infectious agents and continue during life. Some have demonstrated that family and socio economic status affects “either childhood health immediately or possibly for years afterwards, the effects being only partly moderated by later changes” (Charles Miller and Salkind 2002).

Although researchers in this decade have proposed several answers concerning the association between socio economic levels and health (Adler, Boyce et al. 1994; Ostrov and Adler 1998 ; Adler and Ostrov 1999; Pallasaho, Lindström et al. 2004; Dales, Choi B et al. 2002), still one question is not well understood: whether socio-economic status influences asthma and respiratory symptoms or vice versa (Weitzman, Sobol et al. 1990; Rona 2000; Cesaroni, Farchi et al. 2003; Basagaña, Sunyer et al. 2004; Pallasaho, Lindström et al. 2004).

2.1 Socio economic status definition

There is a body of researchers who have defined socio-economic status. Brown et al (2004) reviewed the meaning of socio economic status to present a comprehensive identification. Based on Brown et al (2004), socio-economic status indicates how individuals and groups are ‘accepted’ in a society. Winkleby et al (1992) and Ostrov and Alder (1998) have stated that socio-economic status reflects different modules of the traditional indicators at the individual level, such as income, education, and occupation, which are often used interchangeably even though they are only moderately correlated with one another. Demarest, Reisner et al (1993) and Anderson, Anis et al (2002) concluded that a family's socioeconomic status is based on family income, parental education level, parental occupation, and social status in the community (such as contacts within the community, group associations, and the community's perception of the family).

Epidemiological studies measure the index of socioeconomic disadvantage either using individual indicators such as education, occupation, quality and amenities, house ownership and income (Krieger, Williams et al. 1997; Geronimus and Bound 1998) or by area-based indicators (Geyer and Peter 2000).

2.1.1 Socio economic indicators assessment

In this study, to assess whether different socio-economic levels affect respiratory health individual indicators (education and income) and also areas documented by the Australian Bureau of Statistics (2001) such as areas with low, medium and high socioeconomic status selected to measure socioeconomic disadvantages. The various aspects of the Australian population socio-economic conditions are given by each index. However, socioeconomic status is an inclusive index that refers to a broad range of factors, such as level of social standing, income, education and living conditions (Adler, Boyce et al. 1994; Grundy and Holt 2001).

2.2 Socio economic disadvantage, indoor air quality, asthma and respiratory symptoms

The relationship between socioeconomic status, asthma and respiratory symptoms is not well identified. Studies into the extent to which socio economic status may affect life expectancy (Australian Institute of Health and Welfare 1996; Australian Institute of Health and Welfare 2004; Glover, Hetzel et al. 2004) have concluded low socio economic people or groups have reduced life expectancy, premature mortality, increased disease incidence and prevalence, increased biological and behavioral risk factors for ill health, and lower overall health. In Australia major field efforts have explored the association between social gradients as risk factors and chronic diseases (Australian Institute of Health and Welfare 2004).

Although a few studies have reported no association between respiratory symptoms (Hancox , Milne et al. 2004; Sol'e, Camelo-nunes et al. 2008) and socio economic status D'Amato et al (2002) and Bardana (2001) have demonstrated that low socio economic communities are more exposed to air pollution, dust mites, pets and pests, environmental tobacco smoke and respiratory infection. These studies are consistent with others who have reported increased asthma prevalence in lower socio economic groups (Basagaña, Sunyer et al. 2004; Newacheck and Halfon 2004; Ellison-Loschmann, Sunyer et al. 2007; Yang, Ng et al. 2007). In the line with this, a wide-ranging literature review reveals the impact of socio economic status on respiratory symptoms (Aligne, Auinger et al. 2000; Chen, Tang et al. 2001; El-Sharif, Abdeen et al. 2002; Almqvist, Pershagenz et al. 2005; Asher, Montefort et al. 2006; Ellison-Loschmann, Sunyer et al. 2007). Wilhelm, Qian, and Ritz (2009) have suggested that asthma may be worsened through variety of such factors as economic disadvantage, violence, low social cohesion, and low social capital.

Although studies show poor indoor air quality (IAQ) may have a role in exacerbation of allergic disorders (Parker 2006 ; California Air Resources Board 2005). Rona (2000) and Almqvist et al.(2005) suggest that socio-economic status may also have a key role in the development and progress of the respiratory symptoms and asthma especially in school students.

Investigators have suggested that living in an underprivileged area is a strong predicator of hospital admissions for respiratory symptoms and asthma. Researchers (Weitzman, Sobol et al. 1990; Rona 2000; Cesaroni, Farchi et al. 2003; Basagaña, Sunyer et al. 2004; Pallasaho, Lindström et al. 2004) have predicted that asthma is a complicated respiratory health problem in most socially underprivileged ethnic minorities and poverty may contribute to the development of this illness. The findings of this study were consistent with the results of the studies of Brito, Wurm (2000), Weitzman, Sobol (1990) and Goodman, Stukel (1998) who have suggested asthma is more prevalent among low socio economic communities. A report by Persky, Slezak et al (1998) has shown that the prevalence of respiratory illnesses is higher in minority and low-income populations. This is consistent with studies (Akinbami, LaFleur et al. 2002; Zo¨llner, Weiland et al. 2005) which have shown that asthma related morbidity is higher among children with low socio-economic status and also among black and poor children. In addition, studies have been done (Litonjua, Carey et al. 1999) to show the rate of frequency and severity of respiratory symptoms among school children age 15 and above with low socio-economic status in Great Britain. The results revealed that the prevalence of asthma was 39.8% among children, who had high school education, 22.2% among adults who had college education, and 25.2% among those with post-college education.

In line with this study, a survey from Cairo has demonstrated higher prevalence and increased severity of asthma among lower socio economic status school children (Georgy, Fahim et al. 2006) and a cross sectional survey from Canada has also found a relationship between asthma prevalence and socio economic status (Chen, Tang et al. 2001).

Experts are somewhat uncertain why asthma is so prevalent in low income populations (Akinbami, LaFleur et al. 2002; Basagaña, Sunyer et al. 2004; Almqvist, Pershagenz et al. 2005), but many attribute it to air pollution (Samet, Marbury et al. 1987; Rumchev 2001; Rumchev, Spickett et al. 2002). A comprehensive report from California Air Resources Board (2005) addresses many indoor air pollutants as major causes to irritate eye, nose, throat and respiratory tract. The research has found that aldehydes, as well as some other VOCs and oxidants, are known to be mucous membrane irritants (California Air Resources Board 2005). Formaldehyde is the most commonly identified irritant (Rumchev 2001; Rumchev, Spickett et al. 2002).

A comprehensive survey has shown acute effects of chemical irritants may include respiratory and eye irritation, headache, difficulty in breathing, and nausea (California Air Resources Board 2005). Some of these effects, particularly respiratory symptoms and eye, nose, and throat irritation, can also be experienced with chronic exposure (California Air Resources Board 2005). The report suggests that indoor particulate matter emissions are significant contributors to the adverse impacts on the respiratory system.

There is body of research that suggests socio economic status as a concern on respiratory symptoms. Claudio, Stingone, and Godbold (2006) have suggested that even living in predominantly low socio economic status communities as greater risk factor for asthma. Exploring the impact of social disadvantage on respiratory symptoms, Basagaña et al (2004) have demonstrated that socio-economic status could be explained by current and past individual exposures to lifestyle and environmental factors. In addition to the studies mentioned above, it has been reported (Rashidul Hassana, Luthful Kabir et al. 2002 ; Hedlund, Eriksson et al. 2006) that two groups are more at risk of asthma ; those on a low income and those who are illiterate. A large number of studies have consistently shown that low socio economic status is associated with respiratory symptoms (Corvalán, Amigo et al. 2005; Hedlund, Eriksson et al. 2006).

In order to explain the increase in asthma prevalence, the ‘hygiene hypothesis’ has been launched to clarify rising trends in atopic disease over the last 30 – 40 years, particularly in industrialised/developed countries (Ball, Rodriguez et al. 2000; Stanwell-Smith and Bloomfield 2004).

The ‘‘hygiene hypothesis’’ tends to describe whether a “clean life” in child hood reduces the chance for cross-immunity and increases risk of atopic diseases later(Georgy, Fahim et al. 2006). In line with this concept (Palmer, Valinsky et al. 1999), have demonstrated the relationship between increasing number of people living in the home and asthma as a protective factor . Von Mutius(1994), Ball (2000) , Dales (2002) and the most recent study (Asher, Montefort et al. 2006) have demonstrated that children who do not grow up with other siblings or animals in the house early in life have less developed immune systems due to less exposure to allergens and pollutants, resulting in less tolerance to irritants that may cause asthma.

In agreement with the hygiene hypothesis, Baqueiro, Pontes-de-Carvalho et al (2007) have identified higher prevalence rates of asthma and rhinitis among high socioeconomic status target population. Droste et al (2000) have performed a cross sectional study which explored whether using antibiotics during early childhood may increase the prevalence of asthma. In support of the "hygiene hypothesis", research from Chile has revealed that early childhood respiratory infection would have protective effects on asthma, wheezing and sensitization (Vargas, Bustos et al. 2008). A comprehensive cross sectional study from China has concluded that the prevalence rate of asthma was low in rural zones when compared with other countries (Yeung, Zhang et al. 2002). In agreement with the "hygiene (Lima, Victora et al. 2003) hypothesis", it has been indicated that low socio-economic status and crowded households might be considered as protective factors regarding asthma prevalence in young adult Brazilian residents (Lima, Victora et al. 2003).

Regarding the two different hypotheses, a socio economic index was created using information on family incomes to investigate the impact of indoor air quality in school and homes on respiratory symptoms and asthma among primary school students with different socio- economic backgrounds

In summary, many epidemiological studies have explored associations between environmental pollutants exposure and respiratory symptoms, while other researchers have verified that better hygiene and clean indoor environment may negate the increased prevalence of allergic diseases and respiratory symptoms. Figure III represents a potential model on the relationship between SES, indoor air quality in schools and homes and respiratory symptoms among children

Figures (III) *The impact of socioeconomic status on respiratory symptoms and asthma among school children*

The impact of Socio-economic status on respiratory symptoms among primary school children

VOCs
HCHO
PM2.5
……….

Socio-economic indexes, family income, education and Poverty levels, population

VOCs
HCHO
PM2.5
……….

ENVIRONMENT

Previous respiratory symptoms

Home & School Environment (Airquality)

IAQ House

IAQ School

School children

Previous Respiratory symptoms exaggeration

Other illnesses

Learning performance

Respiratory symptoms

Studied aspect

Chapter Three

Research Methodology

A cross sectional study was chosen to achieve the aims of the investigation into the impact of domestic and school air quality on respiratory symptoms among primary school students from different socioeconomic backgrounds. This study design is an appropriate research approach which provides a cost-effective method of evaluating associations between outcomes and exposures. A cross sectional study provides information on disease prevalence, morbidity or mortality rates (Peat, Mellis et al. 2002). However, “cross sectional studies are ideal for collecting initial information about ideas of association, or for making an initial investigation into hypotheses about causal pathways” (Peat, Mellis et al. 2002).

3.1 Study design

To determine the impact of domestic and school air quality on respiratory symptoms among primary school students from different socioeconomic backgrounds (low and high), this study was conducted within the Perth metropolitan areas. The study was carried out in three stages:

1) Questionnaire survey,

2) Indoor air quality monitoring in schools and 3) Indoor air quality assessment in houses.

3.1.1 Study schools

To serve the purpose of examining whether indoor air quality in schools had an impact on respiratory symptoms, indoor air quality in 36 classrooms of the eleven study schools, which were located in low and high socio economic areas suburban Perth, were measured during summer and winter 2007-8. The sample primary schools were selected from areas documented by the Australian Bureau of Statistics (2001) as areas with low and high socio- economic status. A list of all primary schools within Perth, Western Australia, was obtained from the Department of Education and Training. One hundred and ninety six principals of the primary schools in each area with low and high socio-economic backgrounds were contacted. Out of these 196 contacted primary schools, 25 primary schools from low and high SES were found eligible. The most appropriate criterion for involving primary schools in the survey was considered as public primary school and none of them was located in high traffic zones or industrial areas.

Following contact with principals, 11 primary schools containing 36 classrooms were selected to investigate for the study. The eleven Western Australia Education Department Primary schools, all located in the city of Perth, public and no adjacent to busy road participated in this study in the year 2007-2008. According to the Australian Bureau of Statistics (2001), the areas of Cloverdale, Bentley, Gosnells, Madington, East Cannington, Langford and Kenwick are defined as areas of low socio economic status. Belmont, Kelmscott, Manning, Osborne Park, Lynwood and Huntingdale have been identified as areas of medium socio economic status, while South Perth, Victoria Park, East Victoria Park, Como and Leeming have been recognized as areas with high socio economic status. The list of all public primary schools in the aforementioned areas was provided from the Department of Education and Training of the Government of Western Australia. The principals of the selected public schools were contacted and asked if they would take part in the study. If the principals agreed to take part in the study, the classrooms with students in grade 2-5 from each school were selected and indoor air quality monitored in each classroom for 8 hours twice a week (once at the beginning of the week and once at the end) during winter and summer. The primary school cleaners were asked about usual cleaning products. The Material Safety Data Sheets (MSDS) for cleaning materials were also reviewed.

The primary schools in the survey were ranked in two levels low socio economic status 6 (16.2%), followed by high socio economic status 5 (13.5%) respectively. These schools teach early primary school students and are situated in residential areas of metropolitan Perth. One of the primary schools was deleted from the survey because it was adjacent to a busy high way .Of the remaining ten primary schools, only two primary schools were renovated during the last five years and these were located in low socio economic status areas. The oldest primary school was built in 1898 and the latest in 1983. Out of ten primary schools, three were built more than a hundred years ago , while two primary schools were between 76 and a hundred years old , followed by one 51 to 75, and two between 26-50 years old. School surveys data show only two of the selected primary schools were built less than twenty five years ago.

3.1.2 Study population

The study population of primary school children

Children criteria were as follows

- Aged between 6-9 years old
- Enrolled in primary school grade 2 -5
- Living in the same suburb as the selected school
- Student's parents or care givers have signed the consent form to allow their children to participate in the study

3.1.3 Sample size

The "null" hypothesis for the study is that there are no differences in prevalence of respiratory symptoms in schools located in areas of low medium and high socio-economic status. To examine the hypothesis sufficiently, adequate numbers of samples of primary school children should be collected. The prevalence of respiratory symptoms in primary school children in Western Australian was estimated as 20% (Robertson, Heycock E et al. 1991; Robertson, Dalton M.F et al. 1998). This study was designed to detect an odds ratio of 2 between schools in different socio-economic status areas, for example, between schools in low, medium and high socio-economic status areas. In the cross sectional study, the required sample size for each group (N) can be calculated using the following formula(Williams 1999): $N = (Z_\alpha + Z_\beta)^2 \frac{p_1(1-p_1) + p_2(1-p_2)}{(p_1 - p_2)^2}$

Based on the formula above, 275 primary school children should be recruited from each of the socio-economic status areas in order to detect an odds ratio of two for the respiratory symptoms between the two socio-economic areas with a 90% statistical power. Within the sample size, we can also detect the odds ratio of two in children with exposure to significantly high levels of pollutants in schools, assuming that one third of primary school children have such exposure in school environments. This study planned to assesses 30 houses in each of the three socio-economic status areas. The estimated levels of pollutants in houses in Western Australia are 16 (SD: 20 μg/m^3) and 32 (SD: 30 μg/m^3) for HCHO and PM10, respectively (Zhang 2004). Based on the power calculation, 825 primary school students are needed. It is also anticipated that we will lose through natural attrition approximately 20% of the sample; hence, a total of 990 primary schoolchildren will be required.

3.2 Study stages

The study stages contain three parts, which are described in detail below.

3.2.1 Stage one questionnaire survey

The goals of the questionnaire survey were related to general information, respiratory symptoms, asthma and other allergic conditions to identify the probable risk factors for respiratory symptoms and asthma in domestic environments.

The questionnaire employed for the study was based on the comprehensive standardized questionnaire of the American Thoracic Society (ATS), with little modification, validated by Rumchev (2001). The questionnaire survey was conducted in eleven primary schools from low, medium and high socio economic areas (from low, medium and high SES suburban during March-May 2007. Firstly, an information letter, a consent form and a questionnaire were sent to parents or guardians through their children's teacher. Parents were encouraged to take part in both parts of the study, questionnaire survey and monitoring of their houses. If they agreed to take part in the study, then they were asked to sign a consent form, complete a questionnaire and return them to the children's teacher. The researcher in the schools' administration offices collected the distributed questionnaires. The questionnaire comprised two parts. The first part of the questionnaire was related to the demographic status and child's health status, child's age, gender, date and country of birth, home address. The child's health status, including current wheeze, bronchitis, and asthma diagnosed by a physician and recent asthma attacks, were covered. Some further questions associated with personal susceptibility, such as child's hay fever, allergy reactions, were asked. Questions were asked about common respiratory symptoms, for example phlegm, cough, whistling and wheeze.

In addition, questions were included asking if the child had ever had asthma and, for the children who are known to be asthmatic cases, to ask if the child had ever had an asthma attack or any medication for asthma in the last 12 months. Runny or blocked nose, itchy rash, sneezing and other symptoms related to hypersensitivity were also covered. Family history and any atopic diseases related to family, such as respiratory symptoms and asthma among siblings, eczema and hay fever in first degree relatives, were also covered.

The second part of the questionnaire was mainly related to the child's domestic environment and his /her socio-economic background. These included parents' employment, family income, number of children in the family and parents' educational levels. Further questions, about maternal and paternal smoking habits, visitors smoking, and exposure to gas appliances, kerosene, space heater, fire places or wood fire, were included. The questionnaire also consisted of questions such as age of dwellings, heating and cooling facilities, floor covering, recent renovation, new furniture and type of cooking (gas or electric). It also included questions related to damp or mould occurring inside the house, pet ownership, type of cleaning products and materials and in the household ventilation and traffic around the location of the residence were also covered in this part.

"Socioeconomic disadvantage can take many forms, including low income, poor education, and unemployment, limited access to health services, living in poor housing and working in an unsatisfactory or unskilled job. Alone or in combination, and over time, these stressful economic and social circumstances have an effect on health and wellbeing" (Australian Institute of Health and Welfare 2004). Socio-Economic Index for Areas (SEIFA) consists of four indexes developed by the ABS. Each index summarizes a different aspect of the socio-economic conditions of the Australian population using a combination of variables from the Census of Population and Housing. The Index of Relative Socio-Economic Disadvantage (2001b) was used to illuminate socio economic effects, which include variables that reflect or measure relative disadvantage. The variables include low-income, low educational attainment, all factors likely to influence how a community copes with changing circumstances (ABS 2001b). To measure family socio economic status, children's parents were asked about the highest qualification of the mother and father and occupation of the mother and father. The average weekly family income was also covered.

3.2.2 Stage two

Sampling assessment exposure to indoor pollutants

To achieve the purpose of investigating the relationship between socio-economic status, indoor air quality in houses and schools' and the prevalence of respiratory symptoms the classrooms and domestic environments were initially inspected for signs of building dampness including visible mould growth on indoor surfaces as well as other signs of building dampness (water leakage, signs of dampness from floor construction such as bubbles under the floor coating, and mouldy odor). Measurements were performed in March 2007. Thirty six classrooms were assessed through monitoring the indoor pollutants twice on each day Monday and Friday during winter and summer seasons. The reason for measurements during two days in a week was to investigate the difference in the level of indoor pollutants and climate parameters in classes between occupied and unoccupied hours by students.

One classroom was not considered because it was being used for other purpose during summer sampling time. Class room details on construction materials, type of ventilation and heating system during winter and summer, cleaning routines, cleaning material safety data sheets (MSDS) and number of pupils present were noted.

During the survey, the following pollutants were measured: volatile organic compounds (VOCs), formaldehyde (HCHO), Particulate Matter with size 10 microns in diameter. They were collected over about eight hours between 8:00 am -15:30 pm, which corresponds to the hours that students are likely to be in the classroom. In each classroom, room temperature and relative air humidity were measured by Tinytalk II Data Loggers during sampling time. Particle matter ($PM_{2.5}$) was also monitored in the each room through use of a DUST TRAK MODEL 8520. Ultra fine particles were monitored indoor twice a day before and after school time during morning and afternoon on the sampling day for 10 seconds through use of a P-TRAK Model 8525.

Home visits were carried out during the winter of 2007 and summer 2008. Samples of formaldehyde and VOCs were collected from the children's bedrooms or living room, in which child spends majority of time for 8 hours with a passive sampler.

The sampler was set at a height of 0.8 m in the open space. The collected samples were transported inside plastic containers with diameters 5 and 10 cm from the field to laboratory and also stored in a refrigerator before analysis. Particulate matter ($PM_{2.5}$) was also measured. Temperature and relative humidity were also monitored in those houses on the sampling day. Ultra fine particles were monitored indoor twice a day during morning and afternoon in the same day for 10 seconds through use of a P-TRAK Model 8525.

3.2.2 Stage two (a)

Indoor air quality assessment in school environment

To examine whether indoor air quality in schools impact on respiratory symptoms and asthma, indoor air quality in 36 classrooms of the ten study schools have been investigated through measuring primary indoor air pollutants including Volatile Organic Compounds (VOCs) ($\mu g/m^3$), formaldehyde (HCHO) ($\mu g/m^3$) and particulate matter with size 2.5 microns in diameter ($PM_{2.5}$) ($\mu g/m^3$). Indoor temperature (TCº) and relative humidity (RH) (%) were also covered.

3.2.2 Stage two (b)

Indoor air monitoring in domestic settings

This stage included domestic indoor air quality monitoring. Representative samples of 30 houses from each area (low, medium and high socio-economic status) were selected. If children's parents signed the consent form to participate in home monitoring, then they were contacted to make an appointment for a home visit. Home visits were carried out twice, during the winter 2007 and summer 2008. Exposure levels to Volatile Organic Compounds (VOCs), formaldehyde (HCHO), Particulate Matter with size

($PM_{2.5}$) ($\mu g/m^3$), temperature (TC°) and relative humidity (RH %) measured in 90 houses for 10 hours in the children's bedrooms and living rooms, which represented the indoor air quality in houses.

3.3 Formaldehyde

There are various methods for monitoring formaldehyde in air. The method using 2, 4 -dinitrophenyl hydrazine (DNPH) described by Levin (Levin and Anderson 1985) is a sensitive and specific method that has been used for several years in the Laboratory of the School of Public Health at Curtin University of Technology. The method utilizes a passive diffuser with a filter containing acidified 2, 4-dinitrophenylhydrazine (DNPH), which reacts with formaldehyde to form the hydrazone irreversibly. The hydrazone is dissolved in accetonitrile and its concentration determined by high performance liquid chromatography (HPLC).

3.4 Passive diffuser

Passive diffuser is a standard three section 37 mm aerosol cassette, with a 37mm glass fiber filter, treated with DNPH and positioned in the middle of the cassette. The filter was prepared by the following producers:

- To prepare the DNPH solution, double re-crystalised (from 4 M HCL) DNPH (0.900g) was dissolved in a solution of 85% ortho-phosphoric acid(1.7 mL), and 1:4 glycerol/ethanol (5mL) in 90 mL of HPLC grade acetonitrile.

- 500 µL of DNPH solution was dispensed with an auto pipette onto the filter, positioned on a sheet of glass.

- Filters were placed in an oven (40-50 ℃) to dry and stored in a desiccator at 75% relative humidity until needed.

The sampling rate (mL/min) for the diffuser was calculated from Fick'slaw.

R=D*A/L*60

Where R is the sample rate, D is the diffusion coefficient of formaldehyde ($0.16\ cm^2\ s^{-1}$)

A is the cross sectional area of the diffuser ($8.04\ cm^2$).L is the diffusion path length (1.0 cm) therefore; the sampling rate was 77.18 mL/min.

3.5 Sample analysis

The procedures of analysis included establishing a standard curve, preparing samples and determining the formaldehyde (HCHO) by the HPLC. To start chemical analysis, samples were prepared based as follows:

The filter from the cassette was removed to set in a 5mL plastic screw cap test tube, adding 3.0mL of HPLC grade acetonitrile and shaking gently for 1 minute. Samples (20µl) were injected into a reversed phase C 4.36 in a Hewlett Packard HP 1100 system with a flow rate of 1.0ml/min and solution composition of 67% HPLC grade methanol and 33% milliQ water. Detection was by measuring UV absorbance at 340nm.

3.6 Volatile Organic Compounds (VOCs)

VOCs were measured in the classrooms and the homes (child's bedroom and living room). To collect the atmospheric VOCs an active sampling method, using a charcoal sorbent tube and relatively small and lightweight battery driven pump, was utilized .The sampling time in classrooms was considered eight hours and in the houses about ten hours continuously with a sampling flow rate of 1l/min. Before sampling, the pump was calibrated with a standard flow rate and flow rate adjusted to 1 L/min. The two ends of the charcoal tube were cut, connected with the pump and the pump was placed at a level of 1 m in the houses (child's bedroom or living room) for the period sampling. After sampling, the two ends of the tube were tightly sealed with caps and the samples were stored in a refrigerator until analysis. For analysis the charcoal tubes were cut in the middle and the active charcoal was poured out and desorbed with 1ml of carbon disulfide. The solvent was transferred into a vial and then the VOCs in the samples were calculated using a gas chromatograph (GC).

A Perkin Elmer Auto system XL gas chromatograph, equipped with a detector (FID at 250°C) and injector, was used to analyze the VOCs for the study. The injection volume was 10µl and data acquisition and results reported using a Turbochrom computer system. The oven temperature was programmed with:

- Initial temperature at 35°C for 6 minutes
- Ramp 1 at 20°C/min to 100 °C holds for 0 min and,

- Ramp 2 at 8°C/min to 200°C holds for 5 min.

3.6.1 VOCs identification

For achieving the study purpose, eleven VOCs possibly related to respiratory symptoms and asthma were chosen for quantitative analysis. The eleven VOCs were benzene, toluene, chlorobenzene, styrene, 1, 2-dichlorobenzene.1, 3-dicholorobenzene, 1, 4- dichlorobenzene, ethlbenzene, m-xylene, o-xylene and p-xylene.The standards of the eleven VOCs were from ULTRA Scientific and this ULTRA standard solution was gravimetrically prepared, and also the analyte concentrations were verified using high resolution gas chromatography. Balances used in the manufacture of this standard were calibrated with weights traceable to NIST in compliance with ANSI/NCSL Z-540-1 and ISO 9001.

3.7 Particulate matter

Particulate Matter (PM_{10} µm) was measured utilizing DustTrak ™ [3]Aerosol Monitor (Model 8520). The sampling duration was 8 hours continually in the class rooms and ten hours in the house (living room and child's room). The Dust Trak monitor is calibrated to the irrespirable fraction of ISO 12103-1, A1 (formerly called ultrafine Arizona test dust) and its aerosol measurement range is 0.001 to 100mg/m^3.

The Dust Trak was programmed with log 12 sampling mode, with a logging interval of 1 min and at the flow rate of 1.7L/min in the study for the of monitoring PM_{10}, a black nozzle (10µm) was threaded onto the DustTrak monitor inlet so that only particles smaller than 10µm (cut-off size for black nozzle) can pass through and all larger particles become trapped in a grit pot.

3.7.1 Dust Trak Maintenance

- Daily or before sampling zero check
- Clean 10 µm nozzle, inlet, and sample tube monthly
- Replace the internal filters when needed
- Adjust the flow rate to 1.71/min regularly

Ultra fine particles ($PM_{2.5}$) ($\mu g/m^3$) were measured in the thirty six study classrooms during summer and winter. On each sampling day, $PM_{2.5}$ $\mu g/m^3$ was monitored twice: 8:00 am and 15:00pm indoors. For students' houses the assessment was carried out twice: summer and winter, in living room and bedroom. P-Trak Ultrafine Counter (Model 8525) (P-Trak) was utilized for the present study. P-Trak has a concentration range of 0 to 5×10^5 particles/cm^3 and a particle size range 0.02 to greater than 1 micrometer. While P-Trak is not able to exclude particles with a size more than 0.1 µm in a diameter, when a number concentration is given by the P-Trak the influence of large particles on the concentration can be considered significant. Hence, it is assumed that the number concentration measured by P-Trak Ultrafine Particle Counter as concentration of ultra-fine particles in this study.

The P-Track is powered in one of two ways: battery (6 AA alkaline) and AC adapter. Sample flow rate is approximately 100 cm^3/ min. Maximum data logging time (adjustable interval) is up to 1000 hours and P-Track can store up to 141 separate tests. An alcohol cartridge is the main part of the machine. One thing should be noted is that when operating, the instrument should not be tilted up. If the instrument is tilted for a period of time; the liquid alcohol may be drawn in to the optical chamber, causing false particle counts and possibly flooding the optics.

3.7.1 Maintenance of P-Trak

- Daily zero check;
- Recharge the alcohol wick before each use;
- Clean inlet screen assembly monthly;

3.8 Temperature and relative humidity

Temperature and relative humidity were measured using Tinytalk II Data Loggers for the study. In the classrooms, the sampling period was about 8 hours and in the domestic settings 10 hours. The sampling interval was 5 minutes for temperature and 15 minutes for relative humidity.

3.8.1 Tinytalk II Data Loggers

Tinytalk II Data Loggers are battery-operated devices, hosted with the OTLM software programme. It has much large memory space to store a maximum of 1800 data readings. The collected data can be easily transferred from the loggers to a computer and the OTLM Software is a powerful and flexible data analysis tool, which can do sample statistic and easily import the data onto a spreadsheet.

- Tinytalk II-Temperature Loggers: 10 K NTC Thermistors are used as a temperature sensor and the temperature measurement range is from -40℃ to 75℃.
- Tinytalk II- relative Humidity Loggers: the operating range is from 0 to 95% relative humidity (RH %).

3.9 Data and statistical analysis

Questionnaire data and measurement data of domestic environments and school were added into SPSS data format before doing statistical analysis. Data checking and screening were done after data entry. Implausible and inconsistent entries were identified and corrected. Data analysis was carried out using SPSS version 17.0 for Windows (SPSS Inc). Missing data were excluded in the statistical analysis.

Chi- square tests were employed to measure the difference in prevalence of respiratory symptoms between schools in different socio-economic areas. To further examine the association between risks of interest and the binary outcomes, logistic regression models were chosen to estimate the odds ratios. For levels of pollutants and other continuous variables, the distributions were investigated first. Respective means or geometric means are presented. ANOVA or corresponding nonparametric methods were used to compare the difference in levels of pollutants in domestic and school environments located in the different socio-economic areas. To further investigate the contributing factors related to levels of pollutants, linear regression models were prepared. Multivariate analysis techniques such as logistic and linear regression analysis have also been conducted to examine the associations and relationships between variables after adjusting for possible confounders. As a group of variables related to socio-economic status, such as family income and parent educational levels were investigated in the current study. Cluster analysis was employed to identify relatively homogeneous groups of subjects based on selected characteristics. Factor analysis has also been conducted to identify underlying variables, or factors, that explain the pattern of correlations within a set of observed socio-economic variables. All the data were analyzed with SPSS and STATA the probability of 0.05 were selected for the statistical significance.

3.9.1 School measurement data

To analyze air pollutants and collected data frequency descriptive procedures were performed. Temperature and humidity, which have a normal distribution, are presented as arithmetic means and their 95% CIs.

To further examine the association between risks of interest and the binary outcome, logistic regression models were applied to estimate the odds ratios. To compare the mean of air pollutants in domestic and school environments located in the different socio-economic areas and between seasons one way ANOVA and Independent-sample T test were performed. Multivariate analysis techniques such as logistic and linear regression analysis have also been conducted to examine the associations and relationships between variables after adjusting for possible confounders.

Cluster analysis was employed to identify relatively homogeneous groups of subjects based on selected characteristics. Factor analysis was conducted to identify underlying variables, or factors, that explain the pattern of correlations within a set of observed socio-economic variables. To measure the significances the same version of statistical analysis and STATA the probability of 0.05 were fitted for schools.

3.9.2 House measurement data

To analyze house measurement data same statistical analysis was also employed. Independent T tests were used to compare the means of air pollutants in domestic settings located in different socio economic status areas.

3.9.2.1 Particulate matter with size 2.5 microns in diameter in houses

Paired sample T tests have been used to compare means of $PM_{2.5}\mu g/m^3$ between summer and winter. Independent Sample T test and ANOVA have also been used to show the differences in PM2.5in houses located in different socio economic areas.

9.2.2 Ultrafine particles in houses

To compare the means of ultrafine particles between children's bedrooms and living rooms paired Sample T test was considered. The correlation coefficients of ultrafine particles in bedrooms and living rooms were calculated to estimate the relationships between them.

3.9.2.3 Formaldehyde in houses

The means of the formaldehyde during winter and summer and between children's bedrooms and living rooms were compared using paired Sample T test.

3.9.2.4 Volatile organic compounds (VOCs) in houses

The concentrations of VOCs were skewed. Therefore median and ranges of VOCS have been presented in the study. However, total VOCs concentration was a normal distribution, paired sample T test was also used to compare the means of total VOCs between summer; and winter. ANOVA analysis was employed to study the differences in levels of total VOCs in houses.

3.10 Questionnaire survey data

Collected data have shown that most variables are categorical variables. Chi-square tests were utilized to measure the relationships among variables. Categorical variables have also been presented as rates (%) and their 95% confidence intervals (95% CIs). The continuous variables are presented as means and standard deviation (SD). To evaluate the differences between variables, independent Sample T test was employed. However, to analyze the collected data that were not found normal distribution nonparametric statistics have been employed to analyze collected data.

3.11 Ethical considerations

To start the study, all school principals were contacted to explain the study objective. If they agree to take part in a detailed of the purpose and significant of study was given to principals. All parents in this study subject have been given an information letter. Accordingly, we described the nature and aims' of study. If they agree to contribute this study, they were asked to sign consent to participate form, before they were invited to complete the questionnaire. They have been given a special code in order to maintain confidentiality and anonymity throughout the study. The sources of information and data have been treated as strictly confidential. All data has been considered strictly confidential. All participants were notified that the study is voluntary and they can withdraw from the study at any time during the study .The data will be kept in locked cupboard in the School of Public Health. After five years as required by the National Health and Medical research Council (NHMRC), the questionnaires will be destroyed and also all data and information will not be assessable for unauthorized persons neither survey period nor latter. Approval letter has been provided from the Curtin University Human Research Ethics Committee and also Department of Education and Training Western Australia.

Chapter Four

Results

Introduction

Millions of students and staff spend a significant portion of their days in public and private school buildings and need to have conditions in which they can thrive, learn and succeed. Many of these buildings are old or may have been built recently but contain environmental conditions that influence the children's respiratory health. This chapter gives the results of the environmental assessment of the levels of pollutants to measure the effects of indoor air quality on respiratory symptoms among primary school students.

In this study 25 schools were approached and 11 primary schools agreed to participate in the current study. Thirty-six class rooms were monitored for volatile organic compounds (VOCs), formaldehyde (HCHO), particulate matter (PM_{10}) and ultra fine particles ($PM_{2.5}$), temperature and humidity were also recorded for eight hours continuously (7:30 am-15:30 pm) twice a week on Monday and Friday. Of the students who participated, 105 children's parent or guardians (in 90 houses) agreed to have monitoring done in their home for the same indoor air pollutants described above.

4.1 Study population

One thousand primary school students (Grade II-Ш-IV) agreed to receive questionnaires and 522 were returned. Out of these, 219 questionnaires were completed and 125 participants agreed to take part in the first and second stages of the survey. Of those 125 participants, 8 families have moved to other States, 5 families have changed living addresses, and 8 families decided not to continue with the second stage.

Although the study found limitations concerning the number of participants with low socioeconomic backgrounds, to support the power of study to give meaningful results, families with low and medium SES based on their incomes and educational levels were combined considered as low SES families. The possible causes of rejection were considered

1-Poor English language understanding

2-Low information concerning respiratory symptoms and asthma

3-Low education levels

4- Busy family

5- Etc.

The response rates between eleven primary schools located in low and high socio economic status were 52.2%. Statistical analyses has shown that 88.6% of children's mothers completed the questionnaires, followed by the children's fathers with 8.9% and 1.9% by others, while 0.6% did not respond.

4.1.1 Demographic distributions

1) Age

The age and gender of participants in target schools are presented in Table 4.1. From the study results presented in Table 4.1 it becomes evident that the eight year old schoolchildren are common age groups in this study. However, no significant difference was seen regarding distribution of asthma between subjects of interest (Table 4.1.1).

Table 4.1 Summary of statistics for age-gender

Gender	Age	Frequency%	Mean	95% CI		Min.	Max.	Sig
				Lower	Upper			
Boy	7 years	45	7.64	7.46	7.81	7.00	7.00	>0.05
	8 years	46						
	9 years	9						
Girl	7 years	50	7.55	7.39	7.70	7.00	9.00	
	8 years	51						
	9 years	2						

2) Gender

As can be seen in Table 4.1 between the two genders the numbers of boys with asthma was higher. However, statistical analyses showed no significant difference between boys and girls with asthma.

3) Family characteristics

3.1 Educational levels

Statistical analyses have demonstrated that 32 % of mothers with low SES had university degree and 25% with TAFE qualifications and 43(%) had graduated from high school. The percent of mothers with high SES graduated from universities was 66.7 %, followed by 15% with TAFE qualifications and 16% of participants had graduated from high school. The differences between educational levels among participating mothers with different socioeconomic status was that those from high SES appeared to be better educated ($P < 0.05$).

Among fathers with low SES, 30.8% had a university degree followed by 31% with TAFE qualifications and 37% graduated from high school. Among the high SES families 59% of fathers had a university degree followed by 20.5% with TAFE and 20.6% graduated from high school. This study found significant differences between educational levels of fathers with low and high SES ($P = 0.007$).

Although there was a significant difference between mothers' type of jobs among low and high SES, the majority reported home duties (36.9%), teachers (7.7%) , followed by nurses (4.6%) and administrative affairs (3.1%,). The other 47.7% of the mothers reported different activities.

3.2) Income and socio economic status levels of participants

The current weekly family income was classified according to ABS (2001) as low and high. Statistical analysis showed that of the 219 families who participated in this study, 44.3 % (97) were classified as the low SES and 55.7 % (122) as high SES families. Of all participants, 63% (138), had reported low income (<1500) and 37% (81) had high income ($1500-$2499) weekly.

3.3 Health characteristics of schoolchildren's parents and siblings

According to the statistical analyses presented in Tables 4.2 the difference between children with low and high SES who have a biological father with hay fever was found to be significant. However, the prevalence of parents' asthma, eczema and siblings' hay fever among subjects of interest with low and high SES were not found to be significant.

Table 4.2 The health characteristics of children parents and siblings

Parents and siblings health	SES	Frequency% (Number)	P value
Mother ever had asthma	Low	21.5 (14)	>0.05
	High	23.1 (9)	
Mother ever had eczema	Low	21.5 (14)	>0.05
	High	25.6 (10)	
Mother ever had hay fever	Low	44.6 (29)	>0.05
	High	38.5 (15)	
Father ever had asthma	Low	15.4 (10)	>0.05
	High	15.5 (6)	
Biological father ever had eczema	Low	6.2 (4)	>0.05
	High	12.8 (5)	
Brothers or sisters ever had asthma	Low	10.8 (7)	>0.05
	High	20.5 (8)	
Biological father ever had hay fever	Low	29.2 (19)	0.082
	High	46.2 (18)	
Brothers or sisters ever had asthma	Low	10.8 (7)	>0.05
	High	20.5 (8)	
Brothers or sisters ever had eczema	Low	15.4 (10)	>0.05
	High	28.2 (11)	
Brothers or sisters ever had hay fever	Low	20 (13)	>0.05
	High	25.6 (10)	

4.2 Health status of study subjects

4.2.1. Respiratory symptoms

In this study the impact of indoor air quality in schools and houses on respiratory symptoms among primary school students from different socioeconomic backgrounds were assessed. The combination of three symptoms in the past 12 months, which included phlegm with a cold, phlegm without cold, chronic cough, are presented as upper respiratory symptoms. Respiratory symptoms were categorized as past and current symptoms. Dry cough at night without the cold, wheezing with a cold, any current wheeze, wheeze during or after exercise and wheeze without exercise and upper respiratory symptoms were considered as “current symptoms”. To evaluate respiratory problems in the past, the other two symptoms” (woken up with shortness of breath “and “wheezing in the past”) were defined as respiratory problems in the earlier period. Of those, the first three items reveal a cold or flu or chronic respiratory infections, while the other seven symptoms indicate asthma.

As shown in Table 4.3, this study did not find a significant difference between respiratory symptoms and asthma either in the past or current symptoms associated with the SES between students.

Descriptive statistical analysis indicates a higher percentage of upper respiratory symptoms among low socioeconomic schoolchildren in the past compared to those with high SES. However, the differences were not found to be significant ($P > 0.05$).

To investigate whether different triggers may affect the severity of wheezing, 12 triggers were assessed. Questionnaire respondents with low and high socioeconomic status were asked to answer if weather, pollen, emotion, fumes, dust, pets, wool clothing, cold or flu, cigarette smoke, foods or drinks, soaps, spray or detergents triggered a wheeze.

Table 4.3 Statistics for respiratory symptoms in the past 12 months and the past between students with low and high SES

Symptoms in the past 12 months	SES	Frequency% (Number)	P value
Upper respiratory	Low	87 (57)	>0.05
	High	82.1 (32)	
Dry cough at night without a cold	Low	30.8 (20)	>0.05
	High	17.9 (7)	
Wheeze with exercise	Low	95.4 (62)	>0.05
	High	100 (39)	
Wheeze without exercise	Low	96.9 (63)	>0.05
	High	100 (39)	
Has your child had wheeze	Low	35.4 (23)	>0.05
	High	30.8 (12)	
Wheezing with a cold or flu	Low	98.5 (64)	>0.05
	High	97.4 (38)	
Symptoms in the past			
Woken up with shortness of breath	Low	98.5 (64)	>0.05
	High	91.9 (37)	
Any ever wheeze	Low	35.4 (36)	>0.05
	High	30.8 (31)	

Table 4.4 shows the possible factors that may process trigger a wheeze. Although the percentage of allergens' impact on wheeze such as pollens (96.9% versus 89.7%), foods or drinks (93.85% versus 87.2%) followed by wool clothing (95.4% versus 87.2%) were apparently higher among low SES participants than compared to high SES positive points, but no significant differences were seen. The findings suggest that factors, such as soap, sprays or detergents, cigarette smoke , emotion, fumes , dust and cold or flu may act as triggers to make wheezing worse among low and high SES study population.

Table 4.4 Triggers a wheeze and SES

In the last 12months	**SES**	**Frequency% (Number)**	**P value**
Soap, sprays or detergents	Low	96.9% (63)	
	High	87.2% (34)	<0.05
Cigarette smoke	Low	96.9% (63)	
	High	89.7% (35)	<0.05
Emotion	Low	96.9% (63)	
	High	87.2% (34)	<0.05
Dust	Low	96.9% (63)	
	High	89.7% (35)	<0.05
Fumes	Low	98.5% (64)	
	High	89.7% (35)	<0.05
Cold or 'flu"	Low	98.5% (64)	
	High	89.7% (35)	<0.05

As part of a child health survey, each family answered questions in association with the prevalence of allergies as diagnosed by doctor to pollens, dust, chemicals, cockroach and pets. The frequency of those susceptibilities were found to be higher with high socioeconomic status students compared with low socioeconomic status schoolchildren .A statistical analysis established significant differences for dust exposure between low and high SES study population (Table 4.4.1).

Table 4.4.1 Summary of statistics for diagnosed susceptibility to allergens

Diagnosed susceptibility to	SES	Frequency% (Number)	P value
Pollen	Low	7.7% (5.0)	>0.05
	High	12.8% (5.0)	
Dust	Low	4.6% (3.0)	<0.05
	High	15.4% (6.0)	
Chemicals	Low	3.1% (2.0)	>0.05
	High	5.1% (2.0)	
Cockroach	Low	12.3% (8.0)	>0.05
	High	10.3% (4.0)	

Table 4.4.2 The prevalence of asthma among low and high SES attending students

SES	Frequency	Percent	P value
Low	18	(27.7%)	>0.05
High	10	(25.6%)	

The overall prevalence of asthma was found to be 26% and children from low SES appeared to have more asthma compared to those with high SES. As can be seen in Table 4.4.2, the difference was not significant (P >0.05).

4.3) Other allergic conditions

To understand the frequency of other allergic conditions between participants with different socioeconomic backgrounds, the percentages of runny or stuffy nose, watery eyes, eczema, hay fever, habitual snoring, itchy rush and other allergic conditions were evaluated using a questionnaire.

Table 4.5 The prevalence of other allergic conditions among students with low and high SES

Allergic conditions	SES	Frequency% (Number)	P value
Runny or stuffy nose	Low	75.4 (49)	>0.05
	High	79.5 (31)	
Watery eyes	Low	49.2 (32)	>0.05
	High	43.6 (17)	
Eczema	Low	33.8 (22)	>0.05
	High	30.8 (12)	
Other allergic conditions	Low	32.3 (21)	>0.05
	High	33.3 (13)	
Hay fever	Low	29.2 (19)	>0.05
	High	33.3 (13)	
Itchy rush	Low	13.8 (9)	>0.05
	High	20.5 (8)	
Habitual snoring	Low	29.2 (19)	>0.05
	High	33.3 (13)	

According to the statistical analyses presented in Table 4.5, students from low socioeconomic backgrounds appeared to have a higher prevalence of allergic reactions when compared with those from high SES areas, although the differences were not found to be significant.

4.4 Dwelling questionnaire

The aims of the dwelling questionnaire and child health questionnaire were to investigate the following hypotheses for the study.

1. There is a difference in prevalence of respiratory symptoms among primary school students with different socio-economic background.

2. There is a difference in exposure levels to VOCs, HCHO and particulate matter $PM_{2.5}$ in homes located in areas with different socioeconomic status.

3. There is a difference in indoor air quality in homes, with different characteristics.

4. There is an association between prevalence of respiratory symptoms in children and indoor air quality in schools and homes.

4.4.1 Residential characteristics

Residential characteristics have been analyzed according to low and high socioeconomic status. The study results show that the majority of the participants with low SES (78.5%) lived in houses older than 10 years and 35 (53.8%) houses from low SES were occupied by four people. The statistical analyses have also revealed that 22 houses were used by high SES families with four residents. Among families with low SES, the analyses demonstrated that 58.5 % of the residences opened windows daily in winter time followed by 87 % in summer.

Table 4.5.1 Comparison of some houses characteristics

Residential characteristics		SES: low Frequency% (Number)	SES: high Frequency% (Number)	P value
Age of house	>1 < 5	4.0 (6.2)	12.8 (5)	>0.05
	> 5<10	12.3 (8)	10.3 (4)	
	>10	78.5 (51)	76.9 (30)	
Busy road	Yes	26.2 (17)	28.2 (11)	>0.05
Nearby to industries	Yes	6.2 (4)	5.1 (2)	
Number of bedrooms	Two	4.6 (30	7.7 (3)	0.086
	Three	53.8 (35)	25.6 (10)	
	Four	29.2 (19)	55.8 (21)	
	Five	6.2 (4)	10.3 (4)	
	>5	3.1 (2)	2.6(1)	
cooking period (Minute)	>15	3.1 (2)	None	>0.05
	<16 > 30	32.3 (21)	33.30 (13)	
	<30 > 45	10.8 (7)	7.7 (3)	
	<45 > 60	27.7 (18)	38.5 (15)	
	<60> 120	8.5 (12)	15.4 (6)	
	<120>180	1.5 (1)	None	
Air conditioner	Yes	52.3 (34)	69.2 (27)	0.091
Ceiling/wall fan	Yes	20 (13)	17.9 (7)	>0.05
Portable fan in	Yes	38.5 (25)	35.9 (14)	
Evaporative cooler	Yes	21.5 (14)	23.1 (9)	
Damp patches	Yes	24.6(16)	10.3 (4)	0.073
Damp clothes	Yes	50.8 (33)	33 (13)	0.085
Use an extractor fan (showering)	Always	70.8 (46)	76.9 (30)	>0.05
	Some times	18.5 (12)	17.9 (7)	
	No installed	6.2 (4)	5.1 (2)	

Similar patterns were noticed among families with high SES as 64% opened in winter and 82.1% in summer. It can be seen from Table 4.5.1that more high SES families (69.2 %) used air conditioners for heating and cooling compared to those from low SES, although the difference was not significant.

As a part of the questionnaire survey, each family answered questions regarding vacuuming mattresses, washing bed linen, using protective mattress on pillows, dry cleaning furniture's and carpet cleaning. The results did not show significant differences between the families from low and high SES areas (P>0.05).

Table 4.5.2 Prevalence of condensation and mould among families

Residential characteristics		**SES: low**	**SES: high**	**P value**
		Frequency% (Number)	**Frequency% (Number)**	
Condensation	Yes	52.3 (34)	2.50 (8)	<0.05
Mould appears	Bedroom	3.1 (2)	1 (1)	<0.05
	Bathroom	56.9 (37)	25.60 (10)	
Mould inside	Yes	60 (39)	30.8 (12)	<0.05

There is body of research that has focused an exposure to condensation and dampness as a risk factor associated with respiratory symptoms and asthma in both adults and children (Yazicioglu, Saltik et al. 1998; Jaakkola, Norman et al. 2002; Zock, Jarvis et al. 2002). As can be seen from Table 4.5.2, descriptive statistical analyses found that there were significant differences in the association with condensation and mould among houses from low and high socioeconomic areas. Our study result reveals that mould and condensation were more prevalent among the families with low SES.

According to the results presented in Table 4.5.3, the most common method of cooking was gas for both low and high SES groups. However, the statistical analysis indicates no significant differences between the time of using stoves among low and high SES families.

Table 4.5.3 Type of cooking stoves

Type of stove	**SES: low**	**SES: high**	**P value**
	Frequency% (Number)	**Frequency% (Number)**	
Gas	64.6 (42)	64.1 (250	<0.05
Electric	24.6 (16)	10.3 (4)	
Both	10.8 (7)	25.6 (10)	

In order to collect accurate information related to cleaning products and possible indoor pollutant exposure in houses, participants in the study were also asked to answer a question about the daily use of cleaning material. The ingredients of reported cleaning materials in the questionnaire survey using the Material Safety Data Sheet (MSDS) were reviewed to identify any possible respiratory irritants. Although the study results confirmed that the frequency of using special house cleaning materials was higher among families with low SES compared with those from high SES areas (23

(35.4%) versus 9 (23.1 %) respectively) there were no significant differences between low and high SES residences (P>0.05).

Although based on study results, the differences between cooking times did not appear significant, the analysis showed that high SES families used extractor fans more during cooking time compared to the families from low SES areas (Table 4.5.4).

Table 4.5.4 Statistics for using extractor fan during cooking time

Using extractor fan during cooking time	SES: low	SES: high	P value
	Frequency % (Number)	Frequency% (Number)	
Always	40 (26)	21.0 (53.8)	<0.05
Some times	24.0 (36.9)	17.0 (43.6)	

The Chi-square test of significance indicated that there was (Table 4.5.5) a significant difference in the frequency of pet owner ship between subjects with different socioeconomic backgrounds.

Table The4.5.5 Comparison of pet's ownership between participants with low and high SES

Pets' ownership (specify)	SES: low	SES: high	P value
	Frequency% (Number)	Frequency % (Number)	
Cat	7.7% (5)	2.6% (1)	<0.05
Dog	29.2% (19)	53.8% (21)	

In this study, guardians and parents were asked questions related to children's bedroom and living room floor covering. The frequency of parquet, wood and carpet were more prevalent among the families with high SES compared with low SES families, as can be seen in Table 4.5.6, there were no significant differences (P >0.05).

Table 4.5.6 Floor covering in child's bedroom and living room

Floor covering in		**SES: low**	**SES: high**	**P value**
		Frequency% (Number)	**Frequency% (Number)**	
Child's bedroom	Carpet	53.8 (35)	64.1 (25)	>0.05
	Tiles	12.3 (8)	2.6 (1)	
	Linoleum	5.0 (7.7)	2.6 (1)	
	Parquet	6.2 (4)	17.9 (7)	
	Others	15.4 (10)	7.7 (3)	
	Wood	3.1 (2)	5.1 (2)	
Living room	Carpet	27.7 (18)	35.9 (14)	>0.05
	Tiles	26.2 (17)	20.5 (8)	
	Linoleum	7.7 (5)	2.6 (1)	
	Parquets	7.7 (5)	17.9 (7)	
	Other	26.2 (17)	10.3 (4)	
	Wood	1.5 (1)	10.3 (4)	

To investigate associations between any renovations and respiratory symptoms, parents were asked about any renovation in the children's bedrooms and living rooms related to new carpets, furniture and wall painting during the past three months. The results did not indicate significant differences (P>0.05).

Table 4.5.7 Statistics for smoking between low and high socioeconomic status

Smoking	SES: low	SES: high	P value
	Frequency% (Number)	Frequency% (Number)	
	64.6 (42)	51.3 (20)	<0.05

As an air pollutant factor, the frequency of smoking was compared between low and high socioeconomic status families. In the sample population, a higher percentage of smoking inside was revealed among low socioeconomic status participants. Table 4.5.7 shows the significance of parents smoking inside.

Parents were asked to assess the ventilation in the children's bed room and living room. According to the study results demonstrated in Table 4.5.8, differences (P = 0.04) were found between parents' evaluations, but the differences were not significant.

Table 4.5.8 Statistics for parent's evaluation of ventilation in the CBR and LR

The general ventilation in		SES: low Frequency% (Number)	SES: high Frequency% (Number)	P value
Child's bedroom (CBR)	Very good	29.2 (19)	38.5 (15)	>0.05
	Good	55.4 (36)	48.7 (19)	
Living room (LR)	Very good	40 (26)	38.5 (15)	>0.05
	Good	40 (26)	51.3 (20)	

4.5 Confirmed or probable risk factors

Several other factors, such as family history of allergic conditions, dampness, condensation and moulds, type of cooking stoves, pets ownership and passive smoking in relation to environmental or heredity have been demonstrated to be likely risk factors for respiratory symptoms, asthma and other allergic symptoms in children. Tables 4.5, 4.5.1, 4.5.2, 4.5.3, 4.5.4 and 4.5.7 illustrate the percentages of those feasible risk factors among low and high socioeconomic groups.

This study found different percentages of those risk factors among groups from low and high socioeconomic status. When the percentages of "mother ever had asthma", "mother ever had eczema", " mother ever had hay fever" , "father ever had asthma" were compared among low and high socioeconomic status groups , the percentages of such risk factors were found to be no higher among lower socioeconomic status families.

It is also evident from the study findings that the percentages of possible risk factors “father ever had eczema”, “father ever had hay fever”, dampness at home (condensation, moulds), “passive smoking” are much higher in the low socioeconomic group. When we compare the prevalence of “pet ownership” among low and high socioeconomic status study samples, the frequency is higher with the high socioeconomic groups.

4.6 Indoor environmental quality assessment in domestic environments

4.6.1 Introduction

This part of the study presents results of the indoor air pollutant measurements in the domestic settings that may have an impact on respiratory symptoms and asthma.

To examine if there are seasonal differences in indoor air pollutants, 105 houses of those participants in the survey were chosen to measure indoor air quality and levels of probable air pollutant during winter 2007, followed by summer term 2008. One of the houses was adjacent to a busy road and was not assessed.

4.6.2 Formaldehyde in domestic environments

To evaluate the levels of possible indoor air pollutants in houses, 104 schoolchildren from low and high socioeconomic status participating in the first and second stages of survey, the formaldehyde levels were measured in children's bedrooms and living rooms during summer and winter terms. In this study, because of the limited

number of participants with low SES, all study subjects with low and medium socioeconomic status were combined as the low SES group. Preliminary statistical analyses have shown that the distribution of data is not normal and therefore non-parametric statistical analyses were applied.

As can be seen in Table 4.6, high levels of formaldehyde were recorded in summer. Furthermore, significantly higher levels of formaldehyde were seen in the low group compared with the high SES group during summer.

Table 4.6 Formaldehyde (μg/m^3) concentrations in living rooms and children's bedrooms

Time	SES	Room	Med.	Range	P value
Winter	Low	LR	**38.98**	129.55	<0.05
	High	LR	**93.50**	147.05	
	Low	CBR	**40.89**	161.49	<0.05
	High	CBR	**58.63**	130.74	
Summer	Low	LR	**127.79**	254.44	>0.05
	High	LR	**65.38**	49.23	
	Low	CBR	**104.12**	379.70	>0.05
	High	CBR	**63.78**	195.73	

Using independent sample T test established significant differences in levels of formaldehyde between houses with and without tiles as floor covering, high levels of formaldehyde were recorded in houses with tiles (Concentrations) ($p = 0.004$) and ($p = 0.01$) respectively.

4.6.3 Volatile organic compounds (VOCs) in domestic environments

In this study, the following volatile organic compounds (VOCs), benzene, heptene, heptane, toluene, methylbenzene, mp-xylene, o-xylene and isopropyl benzene were assessed in houses twice during the winter and summer terms. Statistical analyses showed that there were significant differences in the levels of the VOCs during winter and summer times among the low and high socio economic status areas. Since the data did not follow normal distribution, median levels and nonparametric statistics were used.

Table 4.7.a Median levels of VOCs (μg/m^3) in domestics from low and high SES areas (winter)

SES / Indexes		Benzene	Heptene	Heptane	Toluene
Low	**Med.**	**4.20**	**3.70**	**1.98**	**6.80**
High	**Med.**	**4.16**	**1.90**	**1.34**	**2.65**
P value		>0.05	<0.05	0.072	<0.05

As can be seen from Tables 4.7.a, 4.7.b, 4.7.1.a and 4.7.1.b there were significant differences in VOCs (μg/m^3) median concentrations between low and high SES areas during winter and summer, as the families from low SES were exposed to higher indoor levels of VOCs, although not all statistically significant.

Table 4.7.b Median levels of VOCs (μg/m^3) in domestics from low and high SES areas (winter)

SES / Indexes		Ethyl benzene	mp xylene	o-xylene	Isopropyl benzene
Low	**Med.**	**0.80**	**0.61**	**0.43**	**1.02**
High	**Med.**	**1.09**	**0.67**	**0.37**	**0.90**
P value		<0.05	<0.05	>0.05	>0.05

Table 4.7.1.a Median levels of VOCs (μg/m^3) in domestics from low and high SES areas (summer)

SES / Indexes		Benzene	Heptene	Heptane	Toluene
Low	**Med.**	**13.30**	**6.20**	**6.32**	**14.00**
High	**Med.**	**9.15**	**5.20**	**3.80**	**6.70**
P value		>0.05	>0.05	>0.05	>0.05

Table 4.7.1.b Median levels of VOCs (μg/m^3) in domestics from low and high SES areas (summer)

SES / Index.		Ethyl benzene	mp xylene	o-xylene	Isopropyl benzene
Low	**Med.**	**2.30**	**0.84**	**0.82**	**0.33**
High	**Med.**	**3.22**	**0.90**	**1.96**	**0.38**
P value		<0.05	<0.05	>0.05	<0.05

Further to this, the statistical analyses showed that the indoor concentrations of some VOCs appeared to be significantly higher in families from high SES areas.

Study results presented in Tables 4.7.2 show that the median concentrations of benzene (μg/m^3) in living rooms and children's bedrooms increased during summer. In summer, families from low SES were exposed to significantly higher levels of benzene compared with high SES families.

Table 4.7.2 Median, minimum and maximum levels of benzene (μg/m^3) in the living and children's bedroom measured in winter and summer

Room	SES	Index	Winter	P value	Summer	P value
LR	Low	**Med**	**4.70**	>0.05	**12.8**	<0.05
		Mini	0.70		1.2	
		Max.	34.70		58.6	
	High	**Med**	**1.90**		**7.9**	
		Mini	1.60		2.9	
		Max.	6.43		21.3	
CBR	Low	**Med**	**4.20**	>0.05	**13.4**	>0.05
		Mini	0.10		0.4	
		Max.	28.00		36.9	
	High	**Med**	**4.40**		**9.7**	
		Mini	0.44		2.4	
		Max.	28.40		46.2	

Table 4.7.3 The medians and ranges of heptene (μg/m^3) in the living and children's bedroom measured in winter and summer

Room	SES	Index	Winter	P value	Summer	P value
LR	Low	**Med**	**3.22**	>0.05	**6.10**	>0.05
		Mini	0.10		0.67	
		Max.	10.00		66.70	
	High	**Med**	**1.78**		**3.60**	
		Mini	1.00		2.91	
		Max.	6.00		25.00	
CBR	Low	**Med**	**3.70**	<0.05	6.40	>0.05
		Mini	1.00		0.16	
		Max.	9.00		14.00	
	High	**Med**	**1.90**		**5.25**	
		Mini	0.10		1.00	
		Max.	27.00		41.70	

As illustrated in Tables 4.7.3, the median concentrations of heptene (μg/m^3) in living rooms and children's bedrooms were higher during summer. Higher concentrations of heptene were measured in summer among families from low SES groups

Table 4.7.4 The medians and ranges of heptane (μg/m^3) in the living room and children's bedroom measured in winter and summer

Room	SES	Index	Winter	P value	Summer	P value
LR	Low	**Med**	**2.10**	>0.05	**6.40**	>0.05
		Mini	0.10		0.44	
		Max.	32.10		47.70	
	High	**Med**	**1.96**		**4.10**	
		Mini	0.30		2.70	
		Max.	3.60		8.10	
CBR	Low	**Med**	**1.90**	>0.05	**6.30**	<0.05
		Mini	0.09		0.52	
		Max.	21.30		33.00	
	High	**Med**	**1.30**		**3.70**	
		Mini	0.10		0.67	
		Max.	18.20		32.00	

As can be seen in Table 4.7.4, significantly higher concentrations of heptane (μg/m^3) were detected in both rooms among families from low and high SES during summer. Families from low SES were exposed to significantly higher levels of heptane compared with those from high SES families during summer.

Table 4.7.5 The medians and ranges of toluene (μg/m^3) in the living and children's bedroom measured in winter and summer

Room	SES	Index	Winter	P value	Summer	P value
LR	Low	**Med**	**7.20**	<0.05	**17.30**	<0.05
		Mini	0.55		3.03	
		Max.	40.80		90.10	
	High	**Med**	**1.12**		**3.21**	
		Mini	0.26		2.30	
		Max.	5.90		7.80	
CBR	Low	**Med**	**6.30**	<0.05	**13.40**	<0.05
		Mini	0.10		1.90	
		Max.	36.90		72.00	
	High	**Med**	**3.40**		**7.60**	
		Mini	0.14		1.10	
		Max.	12.20		32.00	

As can be seen in Table 4.7.5, the levels of toluene increased during summer between low SES families when they were compared with high SES. The study results showed that significantly higher concentrations of toluene were measured in families from low SES in comparison with high SES during winter and summer.

As illustrated in Tables 4.7.6 and 4.7.7, the median concentrations of mp_xylene and o-xylene in living rooms and children's bedrooms were higher during summer when compared with high SES families.

Table 4.7.6 The medians and ranges of mp-xylene (μg/m^3)

Room	SES	Index	Winter	P value	Summer	P value
LR	Low	**Med**	**0.53**	>0.05	**0.88**	<0.05
		Mini	0.15		0.31	
		Max.	2.05		4.20	
	High	**Med**	**0.37**		**0.74**	
		Mini	0.20		0.42	
		Max.	0.67		0.91	
CBR	Low	**Med**	**0.63**	>0.05	**0.81**	>0.05
		Mini	0.11		0.33	
		Max.	4.90		2.60	
	High	**Med**	**0.79**		**1.10**	
		Mini	0 .04		0.21	
		Max.	3.30		91.00	

Table 4.7.7 The medians and ranges of o-xylene (μg/m^3)

Room	SES	Index	Winter	P value	Summer	P value
LR	Low	**Med**	**0.32**	>0.05	**0.90**	<0.05
		Mini	0.04		0.07	
		Max.	1.00		6.90	
	High	**Med**	**0.18**		**1.80**	
		Mini	0.15		0.73	
		Max.	0.44		7.60	
CBR	Low	**Med**	**0.44**	>0.05	**0.77**	<0.05
		Mini	0.12		0.01	
		Max.	0.90		8.80	
	High	**Med**	**0.44**		**1.90**	
		Mini	0.12		0.06	
		Max.	1.20		39.50	

Higher concentrations of mp_xylene and o-xylene were measured in summer among families from high SES.

The Mann Whitney test for significance established no significant differences between the median levels of isopropyl benzene ($\mu g/m^3$) in the living rooms and children's bedrooms.

Table 4.7.7.a The medians and ranges of Cummen* ($\mu g/m^3$)

Room	SES	Index	Winter	P value	Summer	P value
LR	Low	Med	1.03	>0.05	0.26	>0.05
		Mini	0.10		0.04	
		Max.	36.40		0.99	
	High	Med	0.78		0.49	
		Mini	0.36		0.04	
		Max.	2.26		0.81	
CBR	Low	Med	0.93	>0.05	0.43	>0.05
		Mini	0.04		0.12	
		Max.	50.50		2.50	
	High	Med	0.90		0.35	
		Mini	0.29		0.00	
		Max.	11.00		1.60	

* Isopropyl_benzene

Table 4.7.8 The medians and ranges of ethyl-benzene (μg/m^3) in the living and children's bedroom measured in winter and summer

Room	SES	Index	Winter	P value	Summer	P value
LR	Low	**Med**	**0.90**	<0.05	**2.60**	>0.05
		Mini	0.06		0.70	
		Max.	7.30		16.40	
	High	**Med**	**1.10**		**2.00**	
		Mini	0.86		1.10	
		Max.	1.70		4.50	
CBR	Low	**Med**	**0.60**	<0.05	**2.20**	<0.05
		Mini	0.06		0.83	
		Max.	4.90		7.80	
	High	**Med**	**1.10**		**3.50**	
		Mini	0.10		0.80	
		Max.	6.20		13.10	

Consequently, when median levels of benzene, heptene, heptane, toluene, ethyl benzene, mp_ xylene, o_xylene and isopropyl benzene were compared between low and high socioeconomic status, higher levels of the VOCs were recorded among low socioeconomic areas.

4.6.4 Particulate matter (PM_{10}) ($\mu g/m^3$) in domestic environments

Table 4.8 presents the median, minimum and maximum of PM_{10} ($\mu g/m^3$) measured in living and child's bedrooms in participating households during winter and summer.

Table 4.8 Descriptive statistics for (PM_{10}) ($\mu g/m^3$) between the low and high SES groups during winter and summer

Room	SES	Index	Winter	P value	Summer	P value
LR	Low	Mean	81.13	<0.05	43.38	>0.05
		Med.	**58.50**		**34.83**	
		Range	373.31		138.62	
	High	Mean	44.28		27.19	
		Med.	**44.00**		**27.33**	
		Range	67.00		24.33	
CBR	Low	Mean	72.62	<0.05	40.10	<0.05
		Med.	**60.00**		**31.66**	
		Range	184.33		81.33	
	High	Mean	55.59		29.55	
		Med.	**47.16**		**26.66**	
		Range	138.65		67.62	

As evident from the descriptive statistical analysis shown in Table 4.8, families from low SES are exposed to higher levels of PM_{10} in winter and summer, although the differences are not all significant.

Table 4.8.1 Descriptive statistics for (PM_{10}) ($\mu g/m^3$) between low and high SES groups during winter and summer

SES	Index	Winter	P value	Summer	P value
Low	Mean	76.55	>0.05	41.61	<0.05
	Med.	**60.00**		**31.66**	
	Range	373.31		138.62	
High	Mean	53.56		29.13	
	Med.	**45.66**		**26.66**	
	Range	138.65		67.62	

In this study, our results have shown that families from low socioeconomic groups are more exposed to PM_{10} ($\mu g/m^3$) in summer followed by winter time (Table 4.8.1).

4.6.5 Ultra-fine particles in domestic environments

To investigate the relationship between ultra fine particles, indoor air and respiratory symptoms, 104 samples were measured twice (am) and (pm) during winter and summer within living and children's bedrooms.

As can be seen from Table 4.9, statistical analysis indicates that there is a significant difference in the number of ultra-fine particulates ($P < 0.05$) measured in living rooms and children's bedrooms between low and high socioeconomic, and families from low SES appearing to be exposed to higher number of ultrafine particles.

Table 4.9 Comparison of numbers of ultra fine particles (number/cc^3) during winter and summer between low and high SES areas

Room	SES	winter		Summer	P value
LR	Low	**Med.**	**2230.64**	**2548.7667**	<0.05
		Mini.	1947.50	2159.7500	
		Maxi.	5430.00	9276.00	
	High	**Med.**	**1553.42**	**1832.9286**	
		Mini.	1625.00	1786.5000	
		Maxi.	910.00	973.00	
CBR	Low	**Med.**	**1855.47**	**2261.7286**	<0.05
		Mini.	1520.00	1662.0000	
		Maxi.	5836.50	12636.00	
	High	**Med.**	**1935.98**	**1733.8906**	
		Mini.	1443.25	1613.7500	
		Maxi.	11146.0	1679.00	

4.7 Indoor environmental quality assessment in school environments

4.7. 1 Schools general information

To provide accurate information involving schools, “School questionnaires” was distributed among school staff, who knew the school construction accurately. In this study, 29.9% of primary schools were built about 51-75 years ago and 31.6 % of schools’ buildings were established 76-100 years ago, followed by 27.4% of schools which were built more than 100 years ago. Of those participating schools in this study 73.5% used a gas heater system in winter term, while 15.4% of target schools

were heated by reverse cycle air conditioners and gas heater. The school questionnaire survey has shown that 88.9% of those schools that had air conditioners used them during summer as a cooling system.

Although ceiling or wall fans were used as a cooling system during summer time 57.3 % of schools, in the same time 38.5% of target schools were using evaporative coolers. The school questionnaire also provided useful information regarding cleaning procedures and floor coverings. The cleaning processes included vacuuming (88.9%), of those schools that had air conditioner used it during summer as a cooling system.

Although ceiling or wall fans were used as a cooling system during summer time 57.3 % of schools, at the same time 38.5% of target schools were using evaporative coolers. The school questionnaire also provided useful information regarding cleaning procedures and floor coverings. The cleaning processes included vacuuming (88.9%), changing rubbish bins (88.9%), cleaning tables (88.9%) and cleaning carpet (77.8%). The majority of schools had tiles and linoleum (64%) as floor coverings, followed by carpet (34.2%) respectively.

4.7.2 Formaldehyde in schools

Table 4.10 demonstrates the concentrations of formaldehyde (μg/m^3) during four sampling times

Socioeconomic status		Formaldehyde winter		Formaldehyde summer	
		Monday	Friday	Monday	Friday
low	Mean	62.92	45.23	68.79	130.09
	Median	59.06	31.30	66.95	136.48
	Minimum	20.33	17.17	16.04	12.17
	Maximum	139.28	141.03	132.00	198.00
High	Mean	89.80	76.96	59.80	52.91
	Median	75.32	73.45	58.60	45.58
	Minimum	26.17	17.17	20.78	13.38
	Maximum	193.25	112.06	80.00	189.94
P value / SES	low	Monday- Friday (w)		Monday- Friday (s)	
		<0.05		<0.05	
	High	0.071 (Marginal)		<0.05	

The numbers of formaldehyde samples collected were 104 during winter and summer terms, Monday and Friday respectively. Formaldehyde median levels for schools have been classified in the groups of low and high socio economic status with 65 and 39 classrooms respectively. Nonparametric testing was performed to present the differences of formaldehyde concentrations, as the data was not normally distributed. As can be seen from Tables 4.10 children who attended schools in low

SES areas were exposed to higher levels of formaldehyde in summer but to lower levels in winter compared to those in school from high SES areas.

4.7.3 Volatile organic compounds (VOCs) in schools

To evaluate volatile organic compounds levels, 52 indoor air samples were collected twice on Monday and Friday during winter and summer 2007 and 2008 from schools with low and high SES for benzene, heptene, heptane, toluene, ethylbenzene, mp-xylene, o-xylene and isopropyl benzene. Statistical analyses found different concentrations of volatile organic compounds among schools of different SES. Table 4.11 and Table 4.11.1 show analyses for concentrations of VOCs (μg/m^3) in schools from low and high SES groups during winter and summer**.**

Tables 4.11 The mean ambient concentrations of VOCs (μg/m^3) in schools

SES	Indx.	Benzene		Heptene		Heptane		Toluene	
		(W)	(S)	(W)	(S)	(W)	(S)	(W)	(S)
Low	Mean	1.32	0.68	0.58	0.38	0.5 1	0.38	0.57	0.60
	Med.	0.8 1	0.61	0.65	0.27	0.5 2	0.31	0.51	0.57
	Min.	0.14	0.15	0.22	0.15	0.15	0.10	0.07	0.23
	Max.	7.02	1.87	0.80	0.81	1.10	1.65	1.27	2.05
High	Mean	0.87	4.44	0.41	0.44	049	0.57	0.54	0.49
	Med.	0.79	0.46	0.42	0.35	0.60	0.59	0.58	0.50
	Min.	0.12	0.17	0.15	0.11	0.14	0.10	0.06	0.26
	Max.	0.78	0.96	0.76	0.74	1.03	0.69	1.03	0.78
P value		0.081	<0.05	>0.05	>0.05	<0.05	>0.05	>0.05	<0.05

The study found that during summer and winter terms the concentrations of benzene were less than the recommended levels by WHO (2000) (5-20μg/m^3). However, the median levels of benzene were marginally higher among schools from low socioeconomic status areas during winter.

Table 4.11.1 The mean ambient concentrations of VOCs (μg/m^3) during sampling times in schools

SES	Indx.	Ethylbenzene		m-xylene		o-xylene		Isopropyl benzene	
		(W)	(S)	(W)	(S)	(W)	(S)	(W)	(S)
Low	Mean	0.48	0.98	0.50	0.50	0.45	0.53	0.44	0.39
	Med.	0.47	0.80	0.42	0.59	0.46	0.51	0.47	0.35
	Min.	0.08	0.24	0.13	0.12	0.18	0.24	0.08	0.07
	Max.	1.15	1.68	0.84	0.93	0.84	0.89	0.65	0.77
High	Mean	0.65	0.99	0.62	0.45	0.42	0.43	0.50	0.47
	Med.	0.75	0.99	0.53	0.40	0.38	0.43	0.44	0.49
	Min.	0.14	0.50	0.29	0.25	0.20	0.18	0.25	0.30
	Max.	1.15	1.68	1.09	0.67	0.66	0.65	0.71	0.75
P value		>0.05	>0.05	>0.05	>0.05	<0.05	>0.05	>0.05	<0.05

The descriptive statistical analyses have revealed different levels of VOCs in schools from low and high SES, but they were not significantly different. The study results demonstrated some exceptions regarding concentration of heptane and o-xylene in winter followed by benzene, toluene and isopropyl benzene in summer Table 4.11 and Table 4.11.1

Table 4.11.2 Statistics for concentrations of benzene (μg/m^3) in schools

SES	Index	Winter Monday	Winter Friday	Summer Monday	Summer Friday
Low	**Median**	**1.04 (μg/m^3)**	**0.17(μg/m^3)**	**0.62(μg/m^3)**	**0.49(μg/m^3)**
	Minimum	0.10(μg/m^3)	0.10(μg/m^3)	0.20(μg/m^3)	0.10(μg/m^3)
	Maximum	10.0(μg/m^3)	3.76(μg/m^3)	2.37(μg/m^3)	1.36(μg/m^3)
High	**Median**	**1.27(μg/m^3)**	**0.41(μg/m^3)**	**0.72(μg/m^3)**	**0.18 (μg/m^3)**
	Minimum	0.10(μg/m^3)	0.01(μg/m^3)	0.21(μg/m^3)	0.10(μg/m^3)
	Maximum	3.00(μg/m^3)	1.72(μg/m^3)	45.2(μg/m^3)	0.90(μg/m^3)
P value		>0.05	>0.05	>0.05	>0.05

As evident from study results presented in Table 4.11.2, statistical analyses did not demonstrated significant difference between levels of benzene in Monday and Friday winter followed by summer time among schools from low and high SES areas.

Tables 4.11.3 and 4.11.4, show there are significant differences between median levels of heptene (μg/m^3) and heptane (μg/m^3) among schools from low and high socioeconomic status during winter and summer.

Table 4.11.3 Statistics for concentrations of heptene (μg/m^3) in schools

SES	Index	Winter Monday	Winter Friday	Summer Monday	Summer Friday
Low	**Median**	**0.80(μg/m^3)**	**0.58(μg/m^3)**	**0.35(μg/m^3)**	**0.40(μg/m^3)**
	Minimum	0.10(μg/m^3)	0.13(μg/m^3)	0.08(μg/m^3)	0.01(μg/m^3)
	Maximum	1.00(μg/m^3)	0.97(μg/m^3)	.97(μg/m^3)	0.96(μg/m^3)
High	**Median**	**0.20(μg/m^3)**	**0.50(μg/m^3)**	**.20(μg/m^3)**	**0.60(μg/m^3)**
	Minimum	0.03(μg/m^3)	0.05(μg/m^3)	.01(μg/m^3)	0.20(μg/m^3)
	Maximum	0.67(μg/m^3)	0.97(μg/m^3)	.96(μg/m^3)	0.96(μg/m^3)
P value		<0.05	<0.05	>0.05	>0.05

Table 4.11.4 Statistics for concentrations of heptane (μg/m^3) in schools

SES	Index	Winter Monday	Winter Friday	Summer Monday	Summer Friday
Low	**Median**	**0.22(μg/m^3)**	**0.75(μg/m^3)**	**0.40(μg/m^3)**	**0.20(μg/m^3)**
	Minimum	0.10(μg/m^3)	0.14(μg/m^3)	0.10(μg/m^3)	0.01(μg/m^3)
	Maximum	0.99(μg/m^3)	1.20(μg/m^3)	3.00(μg/m^3)	0.95(μg/m^3)
High	**Median**	**0.84(μg/m^3)**	**0.40(μg/m^3)**	**0.80(μg/m^3)**	**0.41(μg/m^3)**
	Minimum	0.16(μg/m^3)	0.11(μg/m^3)	0.10(μg/m^3)	0.01(μg/m^3)
	Maximum	0.91(μg/m^3)	0.88(μg/m^3)	0.90(μg/m^3)	0.97(μg/m^3)
P value		<0.05	<0.05	<0.05	<0.05

Table 4.11.5 Statistics for concentrations of toluene (μg/m^3) in schools

SES	Index	Winter Monday	Winter Friday	Summer Monday	Summer Friday
Low	**Median**	**0.78(μg/m^3)**	**0.20(μg/m^3)**	**0.64(μg/m^3)**	**.021(μg/m^3)**
	Minimum	0.08(μg/m^3)	0.03(μg/m^3)	0.25(μg/m^3)	0.06(μg/m^3)
	Maximum	1.77(μg/m^3)	0.82(μg/m^3)	2.20(μg/m^3)	1.90(μg/m^3)
High	**Median**	**0.73(μg/m^3)**	**0.40(μg/m^3)**	**0.80(μg/m^3)**	**0.21(μg/m^3)**
	Minimum	0.09(μg/m^3)	0.03(μg/m^3)	0.31(μg/m^3)	0.20(μg/m^3)
	Maximum	1.20(μg/m^3)	0.86(μg/m^3)	0.90(μg/m^3)	0.50(μg/m^3)
P value		>0.05	>0.05	>0.05	>0.05

World Health Organization (2000) has established guide line value for toluene in the range of 5-150 (μg/m^3). As shown in Table 4.11.5 the median concentrations of toluene in this study in schools for low and high SES groups were less than the recommended levels.

Statistical analysis found no significant differences the levels of ethyl-benzene in schools from low and high SES groups (Table 4.11.6).

Table 4.11.6 Statistics for concentrations of ethyl-benzene in schools

SES	Index	Winter Monday	Winter Friday	Summer Monday	Summer Friday
Low	**Median**	**0.79(μg/m^3)**	**0.20(μg/m^3)**	**0.99(μg/m^3)**	**0.66(μg/m^3)**
	Minimum	0.15(μg/m^3)	0.02(μg/m^3)	0.36(μg/m^3)	0.13(μg/m^3)
	Maximum	1.30(μg/m^3)	0.99(μg/m^3)	1.98(μg/m^3)	1.38(μg/m^3)
High	**Median**	**0.90(μg/m^3)**	**0.60(μg/m^3)**	**1.100(μg/m^3)**	**0.92(μg/m^3)**
	Minimum	0.22(μg/m^3)	0.07(μg/m^3)	0.88(μg/m^3)	0.10(μg/m^3)
	Maximum	1.30(μg/m^3)	1.26(μg/m^3)	1.98(μg/m^3)	1.40(μg/m^3)
P value		>0.05	>0.05	>0.05	>0.05

Table 4.11.7 Statistics for concentrations of mp-xylene in schools

SES	Index	Winter Monday	Summer Monday	Winter Friday	Summer Friday
Low	**Median**	**0.46(μg/m^3)**	**0.59(μg/m^3)**	**0.40(μg/m^3)**	**0.40(μg/m^3)**
	Minimum	0.10(μg/m^3)	0.04(μg/m^3)	0.14(μg/m^3)	0.03(μg/m^3)
	Maximum	0.97(μg/m^3)	0.97(μg/m^3)	0.99(μg/m^3)	0.99(μg/m^3)
High	**Median**	**0.52(μg/m^3)**	**0.54(μg/m^3)**	**0.36(μg/m^3)**	**0.64(μg/m^3)**
	Minimum	0.19(μg/m^3)	0.10(μg/m^3)	0.16(μg/m^3)	0.10(μg/m^3)
	Maximum	0.93(μg/m^3)	1.80(μg/m^3)	0.77(μg/m^3)	0.77(μg/m^3)
P value		<0.05	>0.05	>0.05	<0.05

According to the study results presented in Table 4.11.7 higher levels of mp-xylene were measured in schools from low when compared with high SES groups during summer times.

Table 4.11.8 Statistics for o_xylene in schools

SES	Index	Winter Monday	Winter Friday	Summer Monday	Summer Friday
Low	**Median**	**0.68(μg/m³)**	**.040(μg/m³)**	**0.60(μg/m³)**	**0.50(μg/m³)**
	Minimum	0.06(μg/m³)	.01(μg/m³)	.04(μg/m³)	.017(μg/m³)
	Maximum	0.93(μg/m³)	0.88(μg/m³)	1.59(μg/m³)	0.97(μg/m³)
High	**Median**	**0.56(μg/m³)**	**0.21(μg/m³)**	**0.20(μg/m³)**	**0.55(μg/m³)**
	Minimum	.039(μg/m³)	0.01(μg/m³)	.012(μg/m³)	0.07(μg/m³)
	Maximum	0.80(μg/m³)	0.58(μg/m³)	093(μg/m³)	0.90(μg/m³)
P value		<0.05	>0.05	>0.05	>0.05

Table 4.11.9 Statistics for concentrations of isopropyl benzene in school

SES	Index	Winter Monday	Winter Friday	Summer Monday	Summer Friday
Low	**Median**	**0.56(μg/m³)**	**0.32(μg/m³)**	**0.30(μg/m³)**	**0.44(μg/m³)**
	Minimum	0.10(μg/m³)	0.03(μg/m³)	0.02(μg/m³)	.06(μg/m³)
	Maximum	0.90(μg/m³)	0.91(μg/m³)	0.60(μg/m³)	.098(μg/m³)
High	**Median**	**0.66(μg/m³)**	**0.30(μg/m³)**	**0.30(μg/m³)**	**0.60(μg/m³)**
	Minimum	0.31(μg/m³)	0.20(μg/m³)	0.02(μg/m³)	0.25(μg/m³)
	Maximum	0.85(μg/m³)	0.58(μg/m³)	0.90(μg/m³)	0.99(μg/m³)
P value		<0.05	>0.05	>0.05	>0.05

As can be seen from the tables above comparing different VOCs concentrations between schools in low and high SES areas it is evident that higher levels of o_xylene and isopropyl benzene were measured in schools from low SES areas during Monday (winter) followed by Friday (summer).

4.7.4 Particulate matter (PM_{10}) in schools

To evaluate the concentrations of particulate matter with size 10 microns in diameter PM_{10} ($\mu g/m^3$), 104 samples were collected from schools with low SES and high SES. All classrooms were monitored during school hours when students were present. The National Environment Protection Measure (2008) has introduced a standard for ambient air exposure of PM_{10} ($\mu g/m^3$- 24-hour average), which is 50 ($\mu g/m^3$).

Table 4.12 The medians, minimum and maximum concentrations of PM_{10} ($\mu g/m^3$) among target schools

SES	Index	Winter		Summer	
		Monday	Friday	Monday	Friday
Low	**Med**	**54.0($\mu g/m^3$)**	**36.3($\mu g/m^3$)**	**14.3($\mu g/m^3$)**	**22.6($\mu g/m^3$)**
	Min	52.0($\mu g/m^3$)	25.0($\mu g/m^3$)	14.0($\mu g/m^3$)	13.0($\mu g/m^3$)
	Max	58.3($\mu g/m^3$)	67.6($\mu g/m^3$)	16.6($\mu g/m^3$)	23.0($\mu g/m^3$)
High	**Med**	**43.5($\mu g/m^3$)**	**30.0($\mu g/m^3$)**	**16.3($\mu g/m^3$)**	**20.0($\mu g/m^3$)**
	Min	40.3($\mu g/m^3$)	29.3($\mu g/m^3$)	13.3($\mu g/m^3$)	20.0($\mu g/m^3$)
	Max	52.0($\mu g/m^3$)	36.3($\mu g/m^3$)	16.3($\mu g/m^3$)	22.6($\mu g/m^3$)
P value		<0.05	<0.05	0.073	<0.05
***NEPM Guideline value (50 $\mu g/ m^3$ as a 24-hour average**					

Table 4.12 illustrates the median concentrations of PM_{10} in this study among target schools during four sampling times. Statistical analysis demonstrates significant differences between median concentrations of PM_{10} during summer and winter

terms. Students attending schools in low SES areas were exposed to higher concentrations of PM_{10} compared to those in the high SES areas.

4.7.5 Ultra-fine particles in schools

Ultra-fine particles were measured in ten primary schools from areas low and high socio economic status. Recordings were those in mornings (am) followed by afternoons (pm) when children had gone home. Tables 4.13 and 4.13.1 demonstrate medians, minimums and maximums of ultra-fine particle number concentrations among schools' classrooms from low and high SES areas on Monday and Friday.

Table 4.13 Summery statistics of daily number of ultrafine particles /cc^3

Socioeconomic status		Winter		Summer	
		Monday	**Friday**	**Monday**	**Friday**
low	**Median**	**6335.0**	**6660.0**	**3389.5**	**1599.0**
	Minimum	2375.0	683.5	1165.0	703.5
	Maximum	25650.0	21415.00	6775.0	3063.5
high	**Median**	**8540.0**	**2885.0**	**3776.0**	**1689.0**
	Minimum	5380.0	1020.0	1940.5	975.0
	Maximum	15150.0	9210.0	11659.5	2564.5
P value		<0.05	<0.05	<0.05	<0.05

Table 4.13.1 Summary statistics of weekly number of ultrafine particles /cc^3

Socioeconomic status		Winter	Summer
low	**Median**	**7655.0**	**2375.3**
	Minimum	1693.7	1038.7
	Maximum	23532.5	4919.3
high	**Median**	**8177.5**	**2679.7**
	Minimum	3200.0	1457.7
	Maximum	9685.0	6674.2
P value		<0.05	<0.05

As can be seen in Tables 4.13 and 4.13.1, children from schools in high SES areas were exposed to higher number of ultra-fine particles for seasons winter and summer.

However, the Table 4.13 illustrates one exception regarding the daily number of ultrafine particles /cc^3 among schools from high SES areas.

4.8 Temperature and relative humidity in schools

Table 4.14 shows sampling information related to temperature and relative humidity in the schools, relating to the means of the measured indoor temperature (ºC) and relative humidity (RH) (percentage %).

Table 4.14 Geometric mean of the temperature (TºC) and relative humidity (RH %)

Variables / Time	Schools		Domestics		P value
	Mean	Std Dev.	Mean	Std Dev.	
Temperature (ºC)					
Winter	25.9	1.2	26.5	1.14	0.12
Summer	32.7	1.2	21.2	0.8	0.39
Relative Humidity (%)					
Winter	40.8	1.7	39.5	1.7	0.42
Summer	38.2	1.6	38.4	1.6	0.37

The relative humidity and temperature distribution concerning homes and schools were not found to be normal. With the intention of reducing extreme skewness, geometric means were calculated. As can be seen in table 4.14 significant difference was seen between winter and summer temperature (T°C) and relative humidity (RH %) respectively.

4.9 Multivariate analysis

In a statistical model, confounding or irrelevant variables may interact with the dependent and independent variables to influence the results. In the present study, to avoid the effects of confounding factors related to schoolchildren's demographic status, family history of allergic diseases and domestic environment characteristics, multivariate logistic regression models were used to estimate odds ratios (ORs). The logistic regression was used with the purpose of:

1. Examining the relationship between respiratory symptoms and asthma and socioeconomic status.
2. Investigating the association between environmental factors and levels of socioeconomic background.
3. Assessing the factors may affect on asthma and respiratory symptoms significantly.
4. Comparing estimated odds ratios in direction of significant.

Logistic regression analyses were used for socioeconomic status with the intention of determining if there is a significant difference in the potential risk factors for asthma and respiratory symptoms between study populations. Significant ($p<0.05$) and marginally significant variables are considered. The following four statistics were selected to interpret each variable.

1. Odds ratio (OR)

2. Significance is considered (α) probability of an error for the null hypothesis if it is rejected.

3. 95% CI

4. Constant term in logistic regression, because it can state the possibility when all of the independences have the value zero. The SPSS version 17 for windows was selected to perform the logistic regression.

4.9.1 Respiratory symptoms in association with socio-economic status

Multivariate analysis investigated relationships between socioeconomic status and respiratory symptoms among the studied population. However, there was adjustment for ages, gender, family history, mothers' and fathers' jobs, home's adjacent to industrial areas or busy roads, passive smoking and condensation or mould at home..

4.9.2 Asthma in relation to socio-economic status

To calculate odds ratios and significances for associations between asthma and socioeconomic back ground, ages, gender, family history, mothers' and fathers' jobs, home's proximity to industrial areas or busy roads, passive smoking and condensation or mould at home were adjusted. Multivariate Binary Logistic Regression did not demonstrate significant differences between respiratory symptoms and asthma among schoolchildren's from low and high socioeconomic status. Logistic Regression Analysis found statistically significant association between low SES and wheeze among school students (P= 0.005, ORs=3.294; 95%

CI= 1.425 - 7.616). Also low SES could be appeared as a risk factor for asthma (P= 0.033, ORs=2.951 95% CI= 1.091 and 7.977).

4.9.3 Parents' and siblings' histories for asthma and other allergic conditions

After adjustment for age, gender , dampness, moulds, condensation at home and home characteristics in this study, multivariate analysis did not establish significant differences between parents' and siblings' histories of asthma and other allergic conditions with children's asthma among low and high SES school children.

Multivariate analysis demonstrated significant association (p = 0.008) between child's asthma and biological mother's hay fever, with ORs= 0.224 (95% CI 0.074 - 0.679). Also, statistical analysis found marginally significant association between child's hay fever and mother's hay fever (P= 0.079, ORs=0.419, 95% CI= 0. 59 - 1.105). Marginal significance relationship was also found between a child's allergic rash and their mother's eczema (P=0.061, ORs=0.304, CI = 0.087 and 1.059) and with biological father's eczema (P= 0.090, ORs= 0.206, CI = 0. 033 and 1.277). The relationship between parents' and siblings' histories of eczema and other allergic conditions for child's eczema became marginally significant (P= 0.062, ORs=0.359, CI =0.122 and 1.053).

4.10 Respiratory symptoms and asthma in association with the house characteristics

The Mann Whitney test for significance has demonstrated that there are significant differences between respiratory symptoms and house characteristics. The further multivariate analysis after adjusting SES, children's age and gender, parents' employment and education levels has established that families who live near busy roads are four times more likely to have children with upper respiratory symptoms.

According to multivariate regression analysis after adjusting for SES, children's age and gender, parents' employment and education levels, busy roads appeared to be a risk factor for upper respiratory symptoms, wheeze and asthma (Table 4.15).

Table 4.15 Odds ratios of the house characteristic for respiratory symptoms and asthma

Predictor	Respiratory symptoms	Crude ORs	95% CI		P value
			Lower	Upper	
Busy roads	Upper respiratory symptoms	3,922	1.024	15.019	.046
	Wheeze	5.379	7.948	88.837	.000
	Asthma	4.200	1.620	10.892	.003

After the adjustment for confounders (SES, children's age and gender, parents' employment and education levels and house's proximity to a busy road), families who live near industries are almost six times more likely to have children with a dry cough at night (Table 4.15.1)

Table 4.15.1 Odds ratios of the house characteristic for respiratory symptoms and asthma

Predictor	Respiratory symptoms	Crude ORs	95% CI		P value
			Lower	Upper	
Industries	Dry cough	5.455	1.132	26.279	.034
	Asthma	5.379	1.535	18.845	.009
Industries	Snore	5.455	1.382	19.152	.015
Gender		5.379	1.052	6.557	.039

In accordance with statistical analysis after the adjustment for potential confounders, dry cough, asthma and snoring are more than five times more likely for children who live near to industry areas compared to those who do not.

Table 4.15.2 shows the association between respiratory symptoms and using reverse recycle air conditioner systems in winter. The logistic regression analysis showed that air conditioning is a significant risk factor for upper respiratory symptoms, asthma allergy and itchy rash. Children who live in houses with reverse air conditioners were almost 8 times more likely to suffer from upper respiratory symptoms compared to those who did not have reverse air conditioner

Table 4.15.2 Odds ratios of the house characteristic for respiratory symptoms and asthma

Predictor	Respiratory symptoms	Crude ORs	95% CI		P value
			Lower	Upper	
Reverse air conditioner in winter	Upper respiratory	7.661	0.958	1.66	0.05
	Asthma	4.200	1.620	10.892	.003
	Allergy	2.461	1.031	5.874	0.042
	Itchy rash	3.130	1.079	9.080	0.036

The Mann Whitney test for significance (Tables 4.5.1, 4.5.2) has demonstrated that damp clothes, condensation and moulds are some of the major risk factors for respiratory symptoms and asthma.

Table 4.15.3 Odds ratios of the house characteristic for respiratory symptoms and asthma

Predictor	Respiratory symptoms	Crude ORs	95% CI		P value
			Lower	Upper	
Damp clothes	Eczema	3.971	1.493	10.564	0.006
	Upper respiratory	4.103	1.071	15.713	.039
Condensation		4.061	1.269	12.991	.018
	Dry cough at night	2.33	1.042	5.227	0.039
	Eczema	5.058	1.473	17.367	0.010
Moulds	Upper respiratory	4.701	1.227	18.016	.024
	Asthma	3.068	1.191	7.904	.020

Families who reported condensation in their houses are four times more likely to have children suffering from upper respiratory symptoms and asthma.

Based on Logistic Regression Analysis, moulds in houses could increase the risk of asthma among children almost three times (Table 4.15.3). Further Logistic Regression Analysis has established that low socioeconomic status could be a statistically significant risk factor for wheeze. Children from low socioeconomic status backgrounds are three times (ORs =2.99, 95% CI 1.018 - 8.785; p= 0.046) more likely to have a wheeze (Table 4.15.4). Damp patches also appeared to be a significant risk factor for dry cough and wheeze.

Table 4.15.4 Odds ratios of the house characteristic for dry cough at night and wheeze

Predictor	**Respiratory symptoms**	**Crude ORs**	**95% CI**		**P value**
			Lower	**Upper**	
Damp patches	Dry cough at night	3.006	1.00	9.039	0.050
	Wheeze	2.99	1.018	8.785	0.046
SES (low)		4.093	1.671	10.023	0.002

Logistic regression demonstrated that low SES is a statistically significant risk factor for runny or stuffy nose, after the adjustment for children's age and gender, parents' employment and education levels, house's proximity to busy roads and house's proximity to industries.

Table 4.15.5 Odds ratios of the house characteristic for runny or stuffy noseand wheeze

Predictor	Respiratory symptoms	Crude ORs	95% CI		P value
			Lower	Upper	
SES (low)	Runny or stuffy nose	2.775	1.049	7.339	.040
Air condition in summer		2.600	1.024	6.601	0.044
	Wheeze	2.752	1.164	6.507	0.021

Table 4.15.6 Odds ratios of the house characteristic for respiratory symptoms and asthma

Predictor	Respiratory symptoms	Crude ORs	95% CI		P value
			Lower	Upper	
LR linoleum floor covering	Snore	5.00	0.87	8.86	0.072
	Asthma	9.250	1.37	12.09	0.022
LR parquet floor covering	Wheeze	5.60	1.39	9.63	0.016
	Runny or stuffy	8.88	1.02	77.32	0.048
LR carpet floor covering		4.510	1.67	12.17	0.003
	Dry cough at night	2.917	1.30	6.55	0.009
LR tiles floor covering	Wheeze	9.686	1.17	80.10	0.035
CBR carpet floor covering	Itchy rash	3.130	1.08	9.01	0.035
	Asthma	4.205	1.18	15.03	0.027
	Runny or stuffy	6.603	2.34	18.63	0.000
CBR tiles floor covering	Asthma	5.2003	1.39	19.39	0.014

t has also been evident that using air conditioners in the house during summer-time is a major risk factor for runny nose followed by wheeze, increasing the risk by almost three times (Table 4.15.5).

As evident from Table 4.15.6 living rooms and children's bedrooms' floor covering could be a major component of respiratory symptoms and asthma among school children.

4.10.1 Asthma and respiratory symptoms in relation to passive smoking

The data analysis has demonstrated that the frequency of smoking inside is higher among families from low SES when compared with those from high socioeconomic status areas. After adjustment for age, gender, family history of respiratory symptoms and asthma, dampness, moulds and condensation at home, there is still an association between passive smoking and respiratory symptoms (Table 4.15.7).

Table 4.15.7 Odds ratios of the smoking for respiratory symptoms and wheeze

Predictor	**Respiratory symptoms**	**Crude ORs**	**95% CI**		**P value**
			Lower	**Upper**	
Smoking	Upper respiratory	6.860	1.780	26.437	.005
	Wheeze	6.400	2.360	17.354	.000

It is evident that parents who smoke are almost seven times more likely to have children with upper respiratory symptoms and wheeze.

4.10.2 Formaldehyde in houses

The concentrations of formaldehyde in domestic settings were measured during summer and winter. The study result showed that there were no statistically significant differences between concentrations of formaldehyde between families from low and high socioeconomic status. However, according to Logistic Regression Analysis, formaldehyde is a significant risk factor for upper respiratory symptoms (ORs= 1.019, 95% CI 1.000 -1.039; p= 0.050).

4.10.3 Particulate matter (PM_{10}) ($\mu g/m^3$) in houses

Logistic Regression Analysis showed that an indoor concentration of particles PM_{10} increases the risk of asthma by almost one and half times (Table 4.16).

Table 4.16 The crude odds ratios of children respiratory symptoms and asthma with indoor air pollutants

Predictor	Respiratory symptoms	P value	ORs	95% CI	
				Lower	Upper
SES (low)	Asthma	0.071	8.919	0.83	9.24
Total PM_{10}		0.033	1.218	1.02	1.464
Smoking at home		0.050	1.739	0.68	4.48
Mp xylene	Runny stuffy nose	0.075	2.126	0.93	4.88
Ultra fine particles(winter)		0.062	2.121	0.99	3.14
Smoking		0.014	3.272	1.27	8.44
	Watery eyes	0.025	2.550	1.127	5.80
	Snoring	0.093	2.162	0.887	5.32
o- xylene (winter)	Allergy	0.063	4.370	0.927	20.67

4.10.4 Ultra fine particulate matter ($PM_{2.5}$) ($\mu g/m^3$) in houses

After the adjustment for SES, smoking, mould or condensation at home, PM_{10} ($\mu g/m^3$) and any other possible confounders, it was found that there is marginally significant difference between ultra fine particles (winter) and runny or stuffy nose symptoms (Table 4.16).

4.10.5 Volatile organic compounds (VOCs) in houses

As evident from Table 4.16 the multivariate analysis for the association between respiratory symptoms and domestic indoor air in the studied population after adjustment for multi confounders have revealed a marginal association between runny or stuffy nose and mp-xylene levels in winter. Table 4.16 also illustrates the contribution of o_xyelene on child's allergy.

Indoor concentrations of toluene (summer), which is another volatile organic compound, appeared to be also a significant factor for dry cough at night with ORs= 1.042 (95%CI= 1.005 - 1.080; p= 0.025).

4.10.6 Smoking in houses

Regarding respiratory symptoms and asthma, crude odds ratio shows smoking at home increase the risk of asthma by almost twice. Further to this, the Regression Analysis showed that smoking inside could contribute to runny or stuffy nose by almost three and half times (Table 4.16).

There is a strong relationship between watery eyes, snoring and smoking. The statistical analysis indicates that exposure to cigarette smoke at home can increase the risk of snoring in children (Table 4.16).

4.11 Respiratory symptoms and asthma in association with the school characteristics

In the following Table, the results of the association between school characteristics and respiratory symptoms are presented.

Table 4.17 Odds ratios of the school characteristic for respiratory symptoms and asthma

Predictor	Respiratory symptoms	P value	Crude ORs	95% CI	
				Lower	Upper
Adjacent to busy road	Runny nose	0.017	3.37	1.24	9.11
	Dry cough at night	0.004	4.89	1.66	14.38
	Allergy	0.065	3.00	0.94	9.62
	Snore	0.014	3.00	1.25	7.19
New carpet at class room	Asthma	0.069	3.04	0.92	10.08
Wall painted	Watery eyes	0.59	2.14	0.97	4.72
Clean carpet	Hay fever	0.086	6.20	0.77	49.90
Tiles floor covering	Snore	0.064	2.40	0.95	6.06
Linoleum floor covering		0.053	2.19	0.99	4.82
Special cleaning materials		0.056	2.55	0.98	6.66
Ceilings / wall fan (summer)	Wheeze	0.014	2.81	1.23	6.42
Special cleaning materials		0.021	2.94	1.17	7.37

In the multivariate analysis for association between respiratory symptoms and the school characteristics, adjustments were made for parents' socioeconomic status and education, children's age and gender, family history of respiratory symptoms and asthma, smoking at home and other related risk factors at home. As can be seen in Table 4.17, school characteristics could be considered as having a major association with respiratory symptoms and asthma.

According to the statistical analysis, school characteristics including proximity to a busy road, new carpet or other floor covering in classrooms, wall painting, carpet and cleaning could be major contributors to respiratory symptoms and asthma among children.

4.12 The relationship between, respiratory symptoms, socioeconomic status and environmental assessment at school

4.12.1 Formaldehyde in schools

In order to achieve the study's objectives, indoor air quality was assessed in schools during summer and winter. Descriptive statistical analysis has demonstrated that children who attended schools in low SES areas were exposed to higher levels of formaldehyde in summer but to lower levels in winter, compared to those in school from high SES areas. It has also been found that formaldehyde concentrations during winter time could present a risk factor for wheeze with ORs =1.280 (95%CI= 1.002- 1.452; p= 0.009).

4.12.2 Volatile organic compounds (VOCs) in schools

To investigate the effect of volatile organic compounds on human health a number of exposure standards have been established. In Australia, the National Health and Medical Research Council **(**June 1993**)** revealed total VOCs concentrations indoor air 500 ($\mu g/m^3$). This concentration for single VOCs will not be considered more than 50% of the total levels (NHMRC 1993). Table 4.19 demonstrates recommended mean ambient air concentrations for organic pollutants (World Health Organization 2000). The study found different mean ambient concentrations for evaluated VOCs during winter and summer among schools from low and high socioeconomic areas. These concentrations are less than the established NHMRC and WHO recommended standards (chap 3). The present study established significant associations between VOC levels and respiratory symptoms. Table 4.18 shows some VOCs could be considered risk factors for respiratory symptoms.

Logistic Regression Analysis showed that exposure to heptene during summer and winter times could be a significant risk factor for runny nose among children from low SES. Children from low SES are four times more likely to have runny nose in winter (ORs =3.731, 95% CI= 0.959 -14.513; p= 0.058) compared to those from high SES.

Respiratory symptoms	Predictor	P value	Crude ORs	95 % CI	
				Lower	Upper
Asthma	Toluene (s)	0.040	5.59	1.08	29.06
	Ethyl benzene(s)	0.093	2.72	0.85	8.74
Dry cough at night	Heptane (s)	0.050	3.89	1.00	15.13
	Heptane (w)	0.067	2.27	0.94	5.48
Wheeze	Benzene (s)	0.024	1.11	1.01	1.22
	Heptene (w)	0.022	4.87	1.25	18.96
	Toluene (w)	0.099	3.09	0.81	11.79
	mp-xylene (w)	0.022	5.04	1.30	28.16
	mp-xylene (s)	0.074	3.90	0.88	17.34
	o-xylene (w)	0,066	4.36	0.91	21.02
	Cumene (s)	0.056	4.05	0.96	17.06
Runny or stuffy nose	Heptane (w)	0.069	4.13	0.90	18.99
	Toluene (s)	0.021	4.99	1.28	19.55
	m- xylene (w)	0.028	3.29	1.14	9.58
	mp_xylene (w)	0.085	3.46	0.84	14.24
Watery eyes	Heptene (w)	0.011	4.99	1.44	17.32
Allergy	m- xylene (w)	0.018	2.98	1.20	7.39
	Toluene (s)	0.035	4.51	1.11	18.31
	Heptane (s)	0.040	3.86	1.06	14.06
Hay fever	Heptene (w)	0.034	3.17	1.09	9.22
	Cumene (s)	0.020	5.32	1.30	21.83
	Toluene (w)	0.095	1.70	0.91	3.18
	Toluene (s)	0.033	2.50	1.08	5.79
Itchy rash	mp-xylene (s)	0.013	4.50	1.37	14.69
	m- xylene (s)	0.042	3.06	1.04	8.99

Table 4.18 Odds ratios for school indoor air VOCs' and respiratory symptoms

4.12.3 Particulate matter in schools

The effect of particulate matter on health is well documented. While the whole population is affected, susceptibility to adverse effect varies according to age and health conditions (World Health Organization Europe 2005).

The Multivariate Regression Analysis showed that exposure to higher levels of particles (PM_{10}) in classrooms is significantly associated with respiratory symptoms and asthma. It has become evident that PM_{10} concentrations ($\mu g/m^3$) in classrooms could increase the risk of asthma by almost one and a half times (ORs =1.320, CI= 1.042 and 2.052 P= 0.049). It has also been found that PM_{10} ($\mu g/m^3$) concentrations could present a risk for itchy rash (ORs =1.280, 95%CI= 1.002 and 1.452 P= 0.009).

4.12.4 Ultra-fine particulates in schools

As explained in chapter four, the study found significant differences between medians of ultrafine particles at schools from low and high SES groups.

Children from schools in high SES were exposed to a higher number of ultrafine particles in both winter and summer .However, Multivariate Regression Analysis could not demonstrate statistically significant difference between socioeconomic status, ultrafine particles and respiratory symptoms. The statistical analysis showed that ultrafine particulates could increase the risk of upper respiratory almost one and half times (ORs =1.250, 95% CI= 1.302 and 1.952 P= 0.043). Furthermore, Multivariate Regression Analysis indicated that ultrafine particles might be considered as a major indoor air pollutant which increases the risk of asthma among schoolchildren by almost one and a half time (ORs =1.280, CI= 1.002 and 1.452 P= 0.009).

4.13 Temperature and relative humidity in schools

Our result did not demonstrate significant difference in the relative humidity and temperature between schools and houses located in low and high SES areas. However, there was a significant difference in temperature and relative humidity between winter and summer times ($t = 6.8$; $df = 172$; $p = 0.001$) ($t = 11.64 df = 1792$; $p = 0.013$).

Chapter Five

Discussion

Introduction

The impact of indoor air quality on health outcomes among school children is a public health concern as they spend at least 1100 hours per year at school (Leickly 2003). Good indoor air should be the first priority of schools because school children with different socioeconomic status spend up to 10 hours of their time at school (Leickly 2003) and their respiratory system is still maturing and therefore can be adversely affected by poor indoor air quality. .

This study attempts to ascertain the relationships between indoor air quality at schools and houses on asthma and respiratory symptoms among primary school students from different socioeconomic backgrounds. To compare the study results with the guidelines exposure levels different valid references were reviewed. Table 4.19 presents the exposure guidelines for selected air pollutants.

A number of schools from low and high socioeconomic status as well domestic settings located in different socioeconomic areas were selected for the study. To establish a significant difference between concentration levels of pollutants at schools on the first day and other days the environmental assessments were conducted on Monday and Friday during winter and summer terms of 2007 and 2008 respectively.

Table 4.19 Exposure guidelines for selected air pollutants

<table>
<tr><th>VOCs (µg/m^3)</th><th>WHO</th><th>NEPM</th><th>NHMRC</th></tr>
<tr><td>Benzene</td><td>5–20µg/ m^3</td><td>--</td><td rowspan="8">500 µg/ m^3 “A single compound shall not contribute more than 50% of the total.
“Hourly average”</td></tr>
<tr><td>Heptene</td><td>--</td><td>--</td></tr>
<tr><td>Heptane</td><td>--</td><td>--</td></tr>
<tr><td>Toluene</td><td>5–150µg/ m^3
0.26 mg/m^3</td><td>--</td></tr>
<tr><td>Ethylbenzene,</td><td colspan="2">22000 (annual average)
2200 (odour threshold)</td></tr>
<tr><td>Mp-xylene</td><td>--</td><td>1.1 ppm (4800 µg/m^3) measured as a 24-hour average.
Meta-, para- and ortho-xylene</td></tr>
<tr><td>O-xylene</td><td colspan="2">870 µg/ m^3 (annual average)</td></tr>
<tr><td>Isopropyl benzene</td><td>--</td><td>--</td></tr>
<tr><td>*PM2.5 (WHO air quality guideline2005)</td><td>10 µg/ m^3 (annual)
25µg/ m^3 (24 hours)</td><td>8 µg/ m^3 (annual)
25µg/ m^3 (24hours)</td><td>--</td></tr>
<tr><td>PM_{10} (Guideline2005)</td><td>20µg/ m^3 (annual)
50µg/ m^3 (24 hours)</td><td>50 µg/ m^3 as a 24-hour average</td><td>--</td></tr>
<tr><td>Formaldehyde</td><td>25 to 60µg/ m^3</td><td>100 µg/m^3 measured as a 30-minute average.</td><td>120µg/ m^3</td></tr>
</table>

Indoor air quality in schools was assessed over two days for eight hours continuously, from 8am until 3pm. Indoor air quality in home environments, which were selected randomly in different areas, low and high socioeconomic status, were evaluated, as well as schools for ten hours during the day, winter and summer terms. The prevalence of respiratory symptoms and asthma among children with different socioeconomic status was compared.

The study results showed significant differences between concentration levels of indoor air pollutants in schools and houses located in different SES areas. However, socioeconomic status did not affect significantly the prevalence of respiratory symptoms and asthma among schoolchildren from low and high SES. To construe these results meaningfully, many factors had to be considered including possible biases, confounding factors and validity of the study. This chapter will discuss possible associations and the results in detail.

5.1 Validity of the study

5.1.1 Study design

The cross sectional approach was employed to investigate the impact of indoor air quality in schools and domestic settings on respiratory symptoms among primary school students from different socioeconomic status. The cross sectional study provides the results in short time, which is usually the most effective and cost benefit approach in epidemiological studies. This approach also evaluates exposure and outcomes simultaneously. However, the cross sectional study does not allow the identification of cause and effect, which is considered as a limitation of this study. One of the comprehensive achievements of this study is providing basic information concerning the impact of socioeconomic status on indoor air quality, respiratory symptoms and asthma among schoolchildren. This inclusive survey could be the basis for cohort and other longitudinal surveys from an epidemiological point.

5.1.2 Sample size and laboratory internal quality control

In the present study, eleven primary schools Bicton, Millen, Rostrata, South Perth and Shelly Bridge (high), Dawson, Eden hill and Osborne (medium), Queens Park, Beckenham and Bentley (low) were recruited from low, medium and high socioeconomic status areas. The study has been designed to assess 30 houses in each of the three socioeconomic areas as well. Based on power calculation, 825 primary school students were needed. To estimate the total sample size it was considered that the study might lose some participants through natural attrition approximately 20% of the sample. Consequently, 990 schoolchildren were required. Ninety houses were obtained for the study as well. The indoor air samples were analysed using the School of Public Health laboratories at Curtin University of Technology.

5.2 Biases and confounding

The principal purpose of this cross sectional study was to examine the relationship between exposure to air pollutants and respiratory outcomes among schoolchildren from different socioeconomic backgrounds. Bias is any trend that can deviate the study from truth (WHO 2010). It can happen at any stage. A feasible questionnaire bias in terms of socioeconomic status is “income” when questionnaire respondents were asked to display their income. However, in the present study the following approach was employed to establish that information bias was not significant or did not happen.

1. Income was classified using a published document. Socioeconomic status was determined considering their residential areas, established by Australian Bureau of Statistics (ABS 2001b).

2. The selection criteria for parents’ educational levels, which were chosen using Australian Bureau of Statistic document, decreased the effect of this questionnaire bias.

The confounding factors were another matter of concern in the present study. And the following factors were considered as confounders: dampness at home, ambient pollution, passive smoking and family history of respiratory symptoms and allergies. To overcome the potential effect of the confounding factors, logistic regression analysis was applied.

5.3 Socio-economic status

The weight of socioeconomic disadvantages on health is well documented. For example, when poor people or deprived people’s health is compared with well-off people life pattern is a good example. Low income, poor education, unemployment, living in inadequate housing and limited access to health services could be various aspects of socioeconomic disparities (Australian Institute of Health and Welfare

2004). The present study aims to investigate whether socioeconomic disadvantages may affect the indoor air quality, and on the prevalence of respiratory symptoms.

Although the socioeconomic index for areas (SEIFA) describes the average living population conditions, beyond this index the concept of socioeconomic status is neither simple nor well identified. It has been considered that (ABS 2001b; ABS 2006) Socio-Economic Indexes for Areas (SEIFA) is a summary measure for giving different socioeconomic aspects of conditions by geographic areas, which display disadvantages of such areas to compare with other areas in Australia (ABS 2006) .The comprehensive indexes for SAIFA 2006 as 2001b are considered

- “Index of Relative Socio-economic Disadvantage: focuses primarily on the disadvantage, and is derived from such Census variables as low income, low educational attainment, unemployment, and dwellings without motor vehicles (ABS 2001b; ABS 2006).
- “Index of Relative Socio-economic Advantage and Disadvantage: is a continuum of advantage (high values) to disadvantage (low values), and is derived from Census variables related to both advantage and disadvantage (ABS 2001b; ABS 2006).
- “Index of Economic Resources: focuses on financial aspects of advantage and disadvantage, using Census variables relating to residents' incomes, housing expenditure and assets (ABS 2001b; ABS 2006).

- "Index of Education and Occupation": includes census variables relating to the educational attainment, employment and vocational skills (ABS 2001b; ABS 2006).
- In this study, individual indicators, such as income, education and areas documented by the Australian Bureau of Statistics (2001b) as areas with low and high socioeconomic status were chosen to measure socioeconomic disadvantages.

5.4 Pollutants and allergens in schools

Environmental assessment was carried out during winter and summer among selected primary schools followed by residential areas. The measurements showed in general higher levels of air pollutants in schools and houses located in low socioeconomic status areas compared with those in high SES areas. The assessment in school environments showed no confirmed significant differences between mean concentrations of PM ($10\mu g/m^3$) among schools from low and high socioeconomic status during the summer term.

5.4.1 Formaldehyde (HCHO) in classrooms

The IARC (International Agency for Research on Cancer 1998) has classified formaldehyde in Group 2A as a carcinogen. Formaldehyde is one of the volatile compounds (WHO Regional Office for Europe 2001) with different recommended concentration at general places like home and schools, followed by workplace. The natural background concentration for formaldehyde is < 1 $\mu g/m^3$ with a mean of about 0.5 $\mu g/m^3$ (WHO Regional Office for Europe 2001). Formaldehyde concentrations at or above 0.1 ppm (120 $\mu g/m^3$) is an irritant that may cause different symptoms such as watery eyes, burning sensations in the eyes, nose and throat, nausea, coughing, chest tightness, wheezing, skin rashes and other irritating effects (Agar, Gooding et al. July 2001). According to WHO (2002) formaldehyde exposure levels should not exceed 0.05 ppm, and its guideline is 0.08 ppm (100 $\mu g/m^3$) measured as a 30-minute average. NHMRC (National Health and Medical Research Council 1996) recommendation for formaldehyde within domestic premises and schools is 120 ($\mu g/m^3$) or 0.1 (ppm).

The environmental assessments for formaldehyde were done on Monday and Friday during winter and summer among schools with low and high socio economic status. The concentrations of formaldehyde were found to be 119 ($\mu g/m^3$) and 167. ($\mu g/m^3$), 124 ($\mu g/m^3$), 95 ($\mu g/m^3$), 116 ($\mu g/m^3$) and 59 ($\mu g/m^3$) followed by 59 ($\mu g/m^3$) and 177 ($\mu g/m^3$) respectively, which are higher than the WHO and NHMRC guidelines either for summer or winter time. This finding suggests that classrooms may contain different sources of formaldehyde which emit in the selected primary school. However, school design, ventilation system, humidity, using new furniture, maintenance conditions and heating and cooling systems are possible factors which can affect the concentrations of formaldehyde at schools.

Higher concentrations of formaldehyde were measured during winter than summer. This can be explained with the closed windows and the running central heating in classrooms.

5.4.2 Volatile organic compounds (VOCs) in classrooms

Exposure to VOCs emitted into class rooms by furnishings, cleaning products and teaching supplies such as markers and paints could be risk factors for asthma and respiratory symptoms.

Although the study results showed that the concentrations of VOCs in schools from low and high SES groups were below than NHMRC and WHO recommended guideline values, VOCs appeared to be significantly associated with higher prevalence of respiratory symptoms including asthma. This is consistent with the study of Rumchev et.al (2004). Furthermore data from Europe has showed that schools in some European countries frequently have serious indoor environmental quality problems including high levels of Volatile Organic Compounds (VOCs), such as benzene, toluene, styrene and allergens (Carrer, Bruinen et al. 2002).

Daisey et al (1999) and Sun et al (2008) and Kim et al (2007) have shown that the levels of VOCs in classrooms are risk factors for asthma and respiratory symptoms.

5.4.3 Particulate matter (PM_{10}) in schools

Extensive research has been conducted on the hazardous effects of particulate matter on respiratory symptoms, but only a few studies have been done to evaluate the influence of PM_{10} on respiratory symptoms of school children. The National Environment Protection Measure (NEPM-National Environmental Protection Measure 2003) has introduced standard levels of exposure for PM_{10} ($\mu g/m^3$- 24-hour average), which is 50 ($\mu g/m^3$). The present study measured higher median levels of PM_{10} ($\mu g/m^3$) during school times, especially among the low SES groups when we compared them with PM_{10} levels among high SES groups. These results are consistent with the study of Zhang et al (2004), which also found higher levels of PM_{10} ($\mu g/m^3$) during class time.

Horak et al (2002) and Castro et al (2009) have demonstrated that PM10 can affect the pulmonary function of children at school which is agreement with the findings of the present study. Higher levels of PM_{10} were associated with increased prevalence of asthma and other respiratory symptoms.

5.4.4 Ultra-fine particulates in schools

School classrooms are important environment for schoolchildren because they spend a lot time in these locations. While a number of airborne contaminants may be present in schools, the effect of ultrafine particles have received much interest recently as epidemiological and experimental research indicated that ultrafine particles may be predictors for alveolar inflammation (de Hartog, Hoek et al. 2003;

Cheng Fang, Shen Wu et al. 2006). Diapouli et al (2007, 2008) monitored the highest mean indoor concentrations of ultrafine particles in a small carpet-covered library and teachers' office when students and staff were presented at school.

The present study confirmed a significant association between number of ultrafine particles and upper respiratory symptoms. We found that respiratory symptoms are related to ultrafine particle concentrations. These findings are consistent with the literature (de Hartog, Hoek et al. 2003; Kim, Smorodinsky et al. 2004; Cheng Fang, Shen Wu et al. 2006 ; Diapouli, Chaloulakou et al. 2007; Diapouli, Chaloulakou et al. 2008) .

5.5 Temperature and relative humidity in schools

Our results demonstrated no significant difference in the relative humidity and temperature between schools and houses located in low and high SES areas.

However, as would be expected there was a significant difference in the levels of the temperature and relative humidity between winter and summer times ($t = 6.8$; $df = 172$; $p = 0.001$) ($t = 11.64 df = 1792$; $p = 0.01$

5.6 Socio-economic status, pollutants and allergens in houses

The link between socioeconomic status and respiratory symptoms is not simple. There is a hypothesis that higher socioeconomic status may provide families easy access to information regarding their children's health while poor SES could be considered as more disadvantaged. There is a body of research that concludes there is a relationship between SES and health. The prevalence of asthma and wheeze in a rural region in India was higher in students from lower socioeconomic groups with poorer environmental conditions (Pakhale, Wooldrage et al. 2008). Yang et al (2007) have demonstrated higher prevalence of asthma among children with low SES back ground and according to Hedlund et al (2006) low SES may be a risk factor for the development of asthma.

In contrast to these studies and findings, some researchers have demonstrated that children who do not grow up with siblings or animals in the house early in life have less developed immune systems, due to less exposure to allergens and pollutants, resulting in less tolerance to irritants that may cause asthma (Von Mutius, Martinez et al. 1994; Ball, Castro-Rodriguez et al. 2000; Strachan 2000; Dales, Choi et al. 2002 ; Simpson and Custovic March 2007)**.**

According to the results presented in chapters three and four the respiratory symptoms including asthma, wheeze, upper respiratory symptoms appeared to be more prevalent among school children from low SES compared with those from high SES. Those results are consistent with other studies demonstrating a relationship between low SES and asthma (Georgy, Fahim et al. 2006; Hedlund, Eriksson et al. 2006; Baqueiro, Pontes-de-Carvalho et al. 2007)

5.6.1 Formaldehyde (HCHO) in houses

To investigate relationships between the levels of formaldehyde and respiratory symptoms among school children from low and high socioeconomic groups, formaldehyde was measured twice during winter and summer in living rooms and children's bedrooms. Our study results show that the median concentrations of formaldehyde were 39 ($\mu g/m^3$) and 41 ($\mu g/m^3$) in winter followed by 128 ($\mu g/m^3$) and 104($\mu g/m^3$) during summer time in living rooms and bedrooms among low SES groups. At the same time, the levels of formaldehyde were 93.5 ($\mu g/m^3$) and 58.6 ($\mu g/m^3$) during summer and 65.4 ($\mu g/m^3$) and 63.8 ($\mu g/m^3$) during winter in living rooms and bedrooms, respectively, among houses from high SES areas.

Although the exposure levels of formaldehyde were low, they exceeded the recommended levels of 120 $\mu g/m^3$ by NHMRC and of 100 $\mu g/m^3$ by W H O. This is in agreement with the studies of Rumchev et al (2002) and Zhang et al (2004) who have also found similar indoor concentrations in houses and schools.

Franklin et al (2000) in Australia have demonstrated that domestic exposure to formaldehyde at home may irritate the airways to induce subclinical inflammation among healthy children. A case-control study has revealed that formaldehyde raises the risks of atopy and asthma (Rumchev, Spickett et al. 2002)**.** Our results also found a relationship between formaldehyde and higher prevalence of upper respiratory symptoms.

5.6.2 Volatile organic compounds (VOCs) in houses

According to the National Health and Medical Research Council, the maximum permissible level of exposure to VOCs is 500 $\mu g/m^3$. A single compound should not contribute more than 50% of the total hourly average (Table 4.21).

In this study, the following volatile organic compounds (VOCs), benzene, heptene, heptane, toluene, methylbenzene, mp-xylene, o-xylene and isopropyl benzene (cummen) were assessed in houses twice during the winter and summer terms in living rooms and bedrooms. According to the study findings, the median levels of benzene, heptene, heptane, toluene, ethyl benzene, mp,xylene, o,xylene and isopropyl benzene were compared between low and high socio economic status. Higher levels of the VOCs were recorded among low socio economic areas in summer. However, none of the measurements exceeded the NHMRC guidline values.

5.6.3 Particulate matter (PM_{10}) in houses

The present study, demonstrated that smoking is a significant contributor for indoor levels of PM_{10} ($\mu g/m^3$). Furthermore, close distance to industries and busy roads, regular cleaning of carpets and furnishings regularly, households' age, using gas heaters, duration of cooking, number of people living in the house became appeared also as significant contributors of high levels of PM_{10} ($\mu g/m^3$) during winter and summer.

The recommended levels for PM_{10} ($\mu g/m^3$) by NEPM and WHO are 50 ($\mu g/m^3$) (24 hours) (Table 4.19). Statistical analysis found higher levels of PM_{10} during 10 hours monitoring in living rooms and bedrooms among the low SES when compared with the high SES group. The finding suggests there are multiple reasons that may affect PM_{10} ($\mu g/m^3$) concentrations, such as population density, smoking, type of heating system, traffic, closeness to industrial zones and busy roads. Furthermore, our study results reported that total PM_{10} ($\mu g/m^3$) increases the prevalence of asthma. This is consistent with the studies of Zhang et al (2004) and Castro et al (2009), which have concluded that the risk of house exposure to higher PM_{10} for respiratory symptom in children is significant.

5.7 Passive smoking and asthma in children

Tobacco smoke was found to be a significant respiratory irritant, indoor exposure to tobacco may also exacerbate existing asthma (Etzel 2003). There is also body of research which has confirmed the impact of passive smoking on asthma (Cook and Strachan 1997). They summarized the results of reviewed studies regarding asthma and passive smoking. They reported that exposure to passive smoking increase the risk of respiratory symptoms and asthma among children. Our study results demonstrated that smoking at home could increase almost twice the prevalence of asthma.

5.8 Family history of allergic conditions and asthma

The logistic regression analysis demonstrated a significant association between child's asthma and biological mother's hay fever and also a marginally significant association between child's hay fever and the mother's hay fever. These results are consistent with previous studies of, Ball et al (2000) and Zhang et al (2004).

5.9 Dampness, condensation and molds at home and asthma

Exposure to molds may lead to allergic sensitization (Etzel 2003). The RINEH study (2006**)** reported that subjects living in damp housing had a higher prevalence of respiratory symptoms and asthma. Zhang et al (2004) found a significant relationship between exposure to dampness at home and respiratory symptoms and asthma among children. It has been also found that exposure to condensation and dampness are risk factors for respiratory symptoms and asthma neither adults or children (Yazicioglu, Saltik et al. 1998; Jaakkola, Norman et al. 2002; Zock, Jarvis et al. 2002). Our study result showed that there is significant association between damp patches, condensation, and respiratory symptoms including asthma.

Chapter Six

Conclusions and recommendations

It is generally accepted that prevention is much better than cure. This is especially true for asthma, because inflammation of airways is always preventable by providing less harmful environmental exposure to allergens, irritants and social deprivations.

This cross-sectional study aimed to examine the impact of domestic and school air quality on respiratory symptoms among primary school students from different socioeconomic backgrounds. According to the study results, low socioeconomic status has not been found to be protective factor for asthma and respiratory symptoms among schoolchildren. The study results have also shown that schoolchildren from low socioeconomic groups are exposed in general to higher levels of air pollutants in houses and schools. There are several explanations for the higher prevalence of respiratory symptoms and asthma among school children from low socioeconomic status backgrounds:

1. SES itself is found to be a significant contributing factor for higher prevalence of respiratory symptoms.
2. Low socioeconomic status is probably associated with an unhealthy lifestyle from the social, behavioral, nutritional and financial point of view.

3. Asthma prevalence within different socioeconomic status groups was consistently lower in neighborhoods of greater socioeconomic status.

4. We found that respiratory symptoms and asthma prevalence was associated with measures of socioeconomic status. Low SES participants were more likely to have asthma and respiratory symptoms than high SES participants.

5. The family and social environment are also important in the recognition, management, and prevention of asthma symptoms.

6. This study indicates an association between low socioeconomic level, respiratory symptoms and asthma in schoolchildren for both individual and area-based indicators.

For several reasons indoor air quality in schools must be considered as a significant factor for children's health as schoolchildren spend at least 1,100 hours per year at school (Leickly 2003). Further to this children's respiratory and immune systems are still developing and therefore it is of significant importance the environment these children live and study.

To protect respiratory health of school children from different socioeconomic status, different practical procedures could be implemented.

One of the first step should be recognizing the health issues related to indoor pollutants, so the best evaluation and control intervention program are considered and implemented.

Following the results of the current study the following recommendations are proposed.

- To advocate for reduced indoor air pollutants in classrooms by establishing guideline values.
- To provide effective school building maintenance.
- To evaluate indoor air quality at schools periodically.
- To maintain effective ventilation systems.
- To limit staff's use of perfume and fragrances during classes.
- Cleaning materials should be used with caution.
- To over view both frequency of cleaning and materials.
- To develop effective control intervention program at schools.
- To monitor the hazards exposures and the health outcomes.
- To implement medical surveillance and provide information on the health effects and also the priorities for preventive and control actions.
- To do effective school environmental inspections or walk-through surveys.
- To use natural ventilation properly during summer and winter.
- To maintain the air conditioning system on regular basis.
- To replace carpet and tile floor covering with local available materials.

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Appendices I

Abbreviations

ANOVA – Analysis of variance

CBR- Children's bedroom

CI – Confidence Intervals

DEP – Department of Environmental Protection

DNPH – Dinitro Phenyl Hydrazine

GC – Gas Chromatograph

GM – Geometric Mean

H – High

HPLC – High Performance Liquid Chromatography

HVACS – Heating, Ventilating, and Air Conditioning System

IARC – International Agency for Research on Cancer

IAQ – Indoor air quality

LR – Living room

L - Low

Min – Minimum

Max – Maximum

Med – Median

NEPM – National Environment Protection Measure

NHMRC – National Health and Medical Research Council

NSW – New South Wales

OR – Odds Ratio

PM –Particulate Matter

RH – Relative Humidity

SES – Socio Economic Status

SEIFA - Socio-Economic Indexes for Areas (SEIFA) is a product developed especially for those interested in the assessment of the welfare of Australian communities.

S – Summer **W**- Winter

μg/m^3_ Micrograms per cubic meter

US EPA – United State Environmental Protection Agency

US OSHA – United State Occupational Safety and Health Administration

VOCs – Volatile Organic Compounds

WA – Western Australia

WHO – World Health Organization

Curtin
University of Technology

INFORMATION SHEET

Dear principal,

We would like to invite you to participate in a study to investigate some indoor environmental factors that may be affecting childhood respiratory symptoms and asthma. We are looking for young children aged between 6-9 years old, who are studying in primary schools. This research project aims to improve our knowledge about the possible link between substances, which may be present in the indoor air, and the prevalence of asthma among young children. The type of substances that we are interested in come from sources such as gas cooking or heating and vapors from furniture and carpets.

The research project will be conducted in *two* stages described below:

The first stage involves completing a questionnaire, which will give us information about your child's health history and status and his/her home environment.

The second stage will involve measurements of some air pollutants that have been associated with respiratory symptoms and asthma. We would appreciate if you agree to take part in this important research project.

Should you require any further information please do not hesitate to contact my supervisor or me and the contact details are provided. This research project has been approved by the Human Research Ethics Committee and should you have any concern regarding the study please do not hesitate to contact the Secretary of the Committee on 9266 2784.

Yours sincerely,

Mr. Masoud Mostafaee

PhD Researcher

Curtin University of Technology

School of Public Health

Tel: 9266 28 17

Fax: 9266 2958

Email Masoud.Mostafaee@postgrad.curtin.edu.au

Project's supervisor

Dr Krassi Rumchev

Curtin University of Technology

School of Public Health

Tel: 9266 4342

Fax: 9266 2958

Email K.rumchev@cuirtin.edu.au

Curtin
University of Technology

Dear Survey respondent:

In Australia school children spend 1/3 time during a day school age namely 1,100 hours in a year They spend more than 80%-90% of times in indoor school environments. **It is, therefore, vital that schools provide a healthy environment for learning** .**A critical element of a healthy environment is indoor air quality**. **I t directly affects not only levels of health of occupants but also students productivity. It could be distributed different type of acute or chronic disease such as viral, bacterial and asthma allergies**.

This questionnaire has been designed for getting relevant and accurate data collection because we have responsibility for making healthy environment for students.

It should be answered either by person who is very familiar school history or with the facilities in such school. You may ask to consult with other relevant or personnel, such as principals, in answering some questions.

We are conducting this study; ***The impact of domestic and school air quality on respiratory symptoms among primary school students with different socioeconomic backgrounds.'*** with only a sample of randomly selected .You must be sure that every data will be considered confidentially, so the data on your school (s) **is very important.**

Please respond even if the schools selected are new. If you have more questions about the surveyor or questionnaire please do not hesitate and call:

(08) 9266 28 17

Mr. Masoud Mostafaee

Sincerely yours,

Special thanks for your humors cooperation in this very important

INSTRUCTION FOR COMPLETING THIS QUESTIONNAIRE

Section one, general data.

1-Sometimes you will be asked to ***"Circle all that apply***". When this instruction appears you may circle the numbers next to more than one answer. For more information there has been shown an example for you.

If any of the following assertions are true, please circle the number of the appropriate answer.

Circle all that apply,

This school teaches only primary school education students…………………….1

This school is no longer in operation……………………………………………..2

This school is public, not a private school………………………………………..3

If your answers are "teaches only primary school "and 'a public school," circle the numbers 1 and 3.

2-Sometimes you will be asked to' Circle one". When this instruction appears circle the number next to the one best answer. For more information there has been shown an example for you.

Does this school situated in residential location? ***Circle one.***

Yes……………….1 No……………….2

If your answer is "No," circle the number 2.

3-Sometimes you will be asked to write something. For more information there has been shown an example.

When school building was renovated? ……………

SECTION II - SCHOOL INFORMATION

1. Name of school: Please enter the name of the school…………….
2. When did it build? Please enter the year………………………….
3. How old building does it have? Please enter the building age… year(s).
4. Is it your primary school adjacent to busy roads? Yes…….. No…..
5. Is it your primary school adjacent to industries? Yes…….. No….
6. If any of the following statements are true for this school, please circle the number of the appropriate answer. *Circle ALL that apply.*

   This school teaches only primary school educationstudents……………….1

   This school is no longer in operation……………………………….…………2

   This school is public, not a private school…………………………………...3

7. Which of the following grades did this school offer around the first of February 2007? *Circle ALL that apply.*

Grade 1..................... Grade 2.....................

Grade3...................... Grade 4.....................

Grade 5...................

8. What type of heating system do you use in winter? Please select more than one if appropriate.

1. Reverse cycle air conditioner…… 2. Gas heater……….

3. Electric appliance……………….. 4. Wood heater…….

5. Oil heater…………………………. 6.Other (specify)…..

9. Please estimate the number of hours (on average) you would use heating during a day in winter in classes…………………………………………

10. What is the overall condition of the original buildings, the attached and/or detached permanent additions, and the temporary buildings? Refer to the rating scale shown below, and circle one for ***EACH*** category of building. If this school does not have any permanent additions or any temporary buildings on-site, circle "0."

Overall condition includes both physical condition and the ability of the buildings *to meet the* functional requirements of instructional programs.

Rating Scale

Excellent: new or easily restorable to "like new" condition; only minimal routine maintenance required.

Good: only routine maintenance or minor repair required.

Adequate: some preventive maintenance and/or corrective repair required.

Fair: fails to meet code and functional requirement in some cases; failure(s) are inconvenient; extensive corrective maintenance and repair required.

Poor: consistent substandard performance; failure(s) are disruptive and costly; fails most code and functional requirements; requires constant attention, renovation, or replacement.Major corrective repair or overhaul required.

Replace: Non-operational or significantly substandard performance. Replacement required.

SCHOOL QUESTIONNAIRE

<u>On-Site Buildings</u>

Replace	School does not have	Excellent	Good	Adequate	Fair	Poor
N/A	1	2	3	4	5	6

Original buildings	N/A	1	2	3	4	5	6
Attached and/or detached	N/A	1	2	3	4	5	6
Permanent additions to original buildings	N/A	1	2	3	4	5	6
Temporary buildings	N/A	1	2	3	4	5	6

11. What type of cooling system do you use in summer (please select more than one if appropriate)?

Air conditioner...................   Portable fan………………..

Ceiling/ wall fan……………   Evaporative cooler………..

Other (please specify)……..   No cooling………………...

12. Which of the following are regularly done in primary school classes?

Vacuums…………………….   Clean rubbish beans……..

Clean tables………………….   Clean carpets……………

13. How many times has been spent in this primary school from 2 years ago, for controlling listed below. If exact work day hours are not available, give your estimate**. Enter N if none. Circle WN if spending was not needed.**

		2005	2006
a) - Dust control	N	H………………	…………..
b) - Asbestos	N	H…………………	…………...
c) - Safety	N	H…………………	…………...
d) - pollutants	N	H…………………	……………
e) - cockroaches	N	H…………………	….………..
f) - paint	N	H……………………	..…………
g) - Ventilation	N	H……………………	…….........
h) - moles	N	H……………………	………......
i)-Other (Specify)	N	H……………………	…………..
Totals		H……………………	…………..

- **14 Overall, what is the physical condition of each of the building features listed below forthis school's *on-site* buildings?** Refer to the rating scale shown below, and circle one for EACH building feature listed.

Rating Scale

Excellent: new or easily restorable to "like new" condition; only minimal routine maintenance required.

Good: only routine maintenance or minor repair required.

Adequate: some preventive maintenance and/or corrective repair required.

Fair: fails to meet code or functional requirement in some cases; failure(s) are inconvenient;

extensive corrective maintenance and repair required.

Poor: consistent substandard performance; failure(s) are disruptive and costly; fails most code and functional requirements; requires constant attention, renovation, or replacement. Major corrective repair or overhaul required.

Replace: Non-operational or significantly substandard performance. Replacement required.

Building Feature	Excellent	Good	Adequate	Fair	Poor	Replace
Roofs	1	2	3	4	5	6
Framing, floors, foundations	1	2	3	4	5	6
Exterior walls, finishes, windows, doors	1	2	3	4	5	6
Interior finishes, trims	1	2	3	4	5	6
Plumbing	1	2	3	4	5	6
Heating, ventilation, air Conditioning	1	2	3	4	5	6
Electrical power	1	2	3	4	5	6
Electrical lighting	1	2	3	4	5	6
Life safety codes	1	2	3	4	5	6

15. How satisfactory or unsatisfactory is each of the following environmental factors in this school's *on-site* buildings? *Circle one for EACH factor listed.*

Environmental Factor	**Very Satisfactory**	**Satisfactory**	**Unsatisfactory**	**Very Unsatisfactory**
Lighting	1	2	3	4
Heating	1	2	3	4
Ventilation	1	2	3	4
Indoor air quality	1	2	3	4
Acoustics for noise control	1	2	3	4
Flexibility of instructional space (e.g., expandability, convertibility, adaptability)	1	2	3	4
Energy efficiency	1	2	3	4
Physical security of buildings	1	2	3	4

16. Does this school have air conditioning in classrooms, administrative offices, and/orother areas? ***Circle ALL that apply*.**

Yes, inclassroom………………………………………………………….………..1

Yes, in administrative offices …………………………………………………… 2

Yes, in other areas……………………………………….…………….……….. 3

No, no air conditioning in this school at all…………………………………...…. 4

17. How satisfactory or unsatisfactory is the air-conditioning in classrooms, administrative offices, and/or other areas? ***Circle one for EACH category listed*.**

Air Conditioning in:	Very Satisfactory	Satisfactory	Unsatisfactory	Very Unsatisfactory
Classrooms	1	2	3	4
Administrative Offices	1	2	3	4
Other areas	1	2	3	4

18. Regardless of location this school is located in the traffic zone? ***Circle one.***

1. Yes
2. No

19. How many students in this school were absent on the most recent school day?

If none were absent, please circle r zero. 0

If yes, please write the number(s) of student. Number…………………..

20. Could you ordering the three major causes of absenteeism according physician leave sick.

a)- respiratory symptoms	1	2	3	4
b) - Asthma	1	2	3	4
c)-Accident	1	2	3	4

d)-Other (specify ……………………………………………………………).

21. what kind of floor coverings do you have?

a) Carpet
b) Tiles
c) Linoleum
d) Concrete

e) Slate (stone)

f) Parquet

g) Other

22. during the last three months , have the following changes taken place in sample classrooms?

a) New carpeting

b) Walls painted

c) New furniture

d) New wall covering

23. Do cleaners use special classroom cleaning materials? No …Yes …

If yes please specify ………………………………………………………….

24. Do they use recycled materials for rubbish bags? No … Yes …

25. Cleaning Materials Safety Data Sheets (MSDS) are available? No… Yes…

COMMENTS

Do you have any comments you would like to make about primary school facilities?

1) - Yes

2) - No

PLEASE USE THE SPACE BELOW

Curtin
University of Technology

INFORMATION SHEET FOR PARENTS

Dear Parent/Guardian,

We would like to invite you to participate in a study to investigate "**The impact of domestic and school air quality on respiratory symptoms among primary school students with different socioeconomic backgrounds.**"

We are looking for young children aged between 6-9 years old, who are studying in primary schools. The research project will be conducted in *two* stages.

1. Questionnaire survey

2. Indoor air quality measurement in house

The questionnaire will ask questions about the health status of your child and also some house characteristics such as carpet, gas appliances that may be associated with asthma. To complete the questionnaire may take you no longer than ten minutes but it will provide important information about the risk factors for asthma.

The second stage will involve measurements of some air pollutants in your house that have been associated with respiratory symptoms and asthma. If you wish to participate in this stage please sign the consent form and return it to your child's teacher. The researcher will then contact you to make an appointment with you when convenient to visit your house and conduct the monitoring. The visit of your house will take no more than ten minutes.

We would be most grateful if you would be prepared to take part in both stages and indicate your willingness by completing both the consent form and the questionnaire, and return them in the envelope provided.

In both stages the information you provide will be kept confidential and will only be used for research purposes. The results will be presented in an aggregated form, so those individual participants will not be identified.

Your involvement in this study is completely voluntary and you are free to withdraw at any time. Your time to take part in this study is most appreciated and should you have any questions or concerns about the study please no hesitate contact me at Curtin University 92662817. Thank you for your interest and collaboration.

Yours sincerely,

Mr Masoud Mostafaee

PhD Researcher

Curtin University of Technology

School of Public Health

Tel: 9266 2817 |Fax: 92662958| Email Masoud.Mostafaee@postgrad.curtin.edu.au

FORM OF CONSENT

Doctor of Philosophy research

"The impact of domestic and school air quality on respiratory symptoms among primary school students with different socioeconomic backgrounds".

Given names / Surname

I,…………………… ...have read the information explaining affirmative research project "The impact of domestic and school air quality on respiratory symptoms among primary school students with different socioeconomic backgrounds".

I agree to allow ……………………………………….........to participate in the study. (Full name of participant and relationship of participant to signatory)

I understand my child may withdraw from the study at any stage and withdrawal will not interfere with routine care.

I agree that research data gathered from the results of the study may be published, provided that names are not used.

Dated .... day of 200

PARENT OR GUARDIAN'S SIGNATURE…………………………………………….....

(Investigator's full name)

I .... have explained the above to signatories who stated that he/she understood the same.

SIGNATURE ……………………………………………

Curtin University of Technology

CHILD HEALTH QUESTIONNAIRE

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

Name of the child ________________________________

Date and country of birth ________________________________

Name of primary school ________________________________

Residential address ________________________________

____

Post code ________________________________

Contact number and preferred time ____________________________

Date questionnaire completed ________________________________

<u>CHILD HEALTH QUESTIONNAIRE</u>

Please answer by placing a tick in the most appropriate box.

1. Sex of child

   a) Male ◻ b) female ◻

2. Person completing the questionnaire

   a) Child's mother ◻
   b) Child's father ◻
   c) Guardian ◻
   d) Other ◻

   Specify relationship __________________________

3. What is the highest qualification of

	Year 10	**Year 12**	**TAFE**	**University**
a) the mother	◻	◻	◻	◻
b) the father	◻	◻	◻	◻

4. Occupation of the mother ______________________________

5. Occupation of the father ______________________________

6. Average weekly family income is:

a) <$1000 □ b) >$1001< $ 1499 □

c) > $1500<2499 □ d) > $2500

□

7. How many children do you have?

a) One □ b) Two □ c)Three □ d)Four □ e)Five□ f) > 5 □

Please, answer the following questions by placing a tick on "Yes or "No":

8. Has a doctor ever diagnosed your child with asthma?

a) Yes □ b) No □

If "NO" proceed to Q.11

9. <u>In the last 12 months</u>, has your child had an asthma attack?

a) Yes □ b) No □

10. <u>In the last 12 months</u>, your child has taken any medication for asthma?

a) Yes ◻ b) No ◻

11. <u>In the last 12 months</u>, has your child had any of the following symptoms?

	Yes	No
a) Runny or stuffy nose	◻	◻
b) Watery eyes	◻	◻
c) Cough	◻	◻
d) Wheeze	◻	◻
e) Eczema	◻	◻
f) Allergies	◻	◻

If "NO", please go to question 13.

12. In which of <u>the past 12 months</u> did this problem occur?

January ◻ May ◻ September ◻

February □	June □	October □
March □	July □	November □
April □	August □	December □

13. Has your child ever had hay fever?

	Yes	No
	□	□

14. Has a doctor ever said that this child has any allergies to

	Yes	No
a) Pollen	□	□
b) Dust	□	□
c) Chemicals	□	□
d) Cockroach	□	□
e) Pets	□	□

15. Has this child's biological mother ever had

	Yes	No
a) Asthma	□	□

	Yes	No
b) Eczema	◻	◻
c) Hay fever	◻	◻

16. Has this child's biological father ever had

	Yes	No
a) Asthma	◻	◻
b) Eczema	◻	◻
c) Hay fever	◻	◻

17. Has any of this child's brothers or sisters ever had

	Yes	No
a) Asthma	◻	◻
b) Eczema	◻	◻
c) Hay fever	◻	◻

18. <u>In the last 12 months</u>, has your child usually seemed congested in the chest or coughed up phlegm (mucus) with cold.

Yes	No
◻	◻

19. <u>In the last 12 months</u> has your child seemed congested in the chest or

coughed up phlegm (mucus) when he/she did <u>not</u> have a cold.

	Yes	No
	□	□

If "No", please go to question 21.

20. In the <u>last 12 months</u>, has your child usually seem congested in the chest or coughed up phlegm (mucus) on most days (4 or more days a week) for as much as 3 months of the year?

	Yes	No
	□	□

21. In the <u>last 12 months</u>, has your child's chest sounded wheezy during or after exercise?

	Yes	No
If "No", please go to question 30.	□	□

22. <u>In the last 12 months</u>, has your child's chest sounded wheezy when he/she

had not recently taken exercise ?

	Yes	No
	□	□

23. In the last 12 months, has your child had wheezing or whistling in the chest when he/she had a cold or the “flu”?

Yes	No
□	

24. Has your child woken up with shortness of breath at any time in the past?

Yes	No
□	□

25. Has your child ever had wheezing or whistling in the chest at any time in the past?

Yes	No
□	□

26. Has your child ever had wheezing or whistling in the chest in the last 12 months?

Yes	No
□	□

27. In the last 12 months, what has made your child’ wheezing worse? (Please tick all that apply).

Weather	□	Pollen	□
Soap, Sprays or detergents	□	Dust	□
Cigarette smoke	□	Pets	□

Emotion	□	Fumes	□
Wool clothing	□	Cold or "flu"	□
Foods or drinks	□	Other things	□

28. In the last 12 months, how many attacks of wheezing has your child had?

a) None □ b) 1 to 3 □ c) 4 to 12 □ d) More □

29. In the last 12 months, how often, on average, has your child's sleep been disturbed due to wheezing?

a) Less than one night per week □ b) One or more nights per week □

30. In the last 12 months, has your child had a dry cough at night, apart from a cough associated with a cold or chest infection?

Yes	No
□	□

31. Has your child ever had an itchy rash which came and disappeared for at least six months?

Yes No

□ □

32. Does your child snore at night?

Yes No

□ □

If "NO", please go to question 35.

33. Does the snoring occur every night?

Yes No

□ □

If not, how often does it occur?……….…….. times per week.

34. Has your child ever had a tonsillectomy or adenoidectomy?

Yes No

□ □

If "Yes", please give the date……………………………………

Month Year

Do you have any comments you would like to make about your child's health status and his/her home environment? If yes, please use the space below.

COMMENTS

<u>DWELLING QUESTIONNAIRE</u>

The questions in this section relate to your child's home environment. Could you please answer the questions by placing a tick in the most appropriate box.

	Yes	No
1. Is it your house adjacent to busy roads?	◻	◻
2. Is it your house adjacent to industries?	◻	◻

3. How old is your house?

a) Less than 5 years ◻

b) Between 5 and 10 years ◻

c) Greater than 10 years ◻

4. How many people live in the house?…………………………………..

5. How many bedrooms do you have?……………………………………..

a) One bedroom □

b) Two bedrooms □

c) Three bedrooms □

d) Four bedrooms □

e) Five bedrooms or more □

6. How many people share this child's bedroom?

a) Own bedroom □ c) 2 persons □

b) 1 person □ d) 3 or more □

7. What type of heating do you use in winter? Please select more than one if appropriate.

a. Reverse cycle air conditioner □
b. Gas heater □
c. Electric appliance □
d. Wood heater □
e. Oil heater □
f. Other please specify ……………

8. Please estimate the number of hours (on average) you would use heating during a day in winter …………………………………………………………………….

9. How frequently would you ‘air’ your house that is open lots of windows, in winter?

   a. Daily □
   b. Weekly □
   c. Monthly □
   d. Rarely □
   e. Never □

10. What type of cooling do you use in summer (please select more than one if appropriate)?

   a. Air conditioner □
   b. Portable fan □
   c. Ceiling / wall fan □
   d. Evaporative cooler □

Other (please specify) ……………………………………

No cooling □

11. Please estimate the number of hours (on average) you would use air conditioning during a day …………………………………… (no. of hours).

12. How frequently would you ‘air’ your house, that is open lots of windows, in summer ?

□ Daily □ Monthly □ Never

□ Weekly □ Rarely

13. Smoking inside the house

	Yes	No
a) parents	□	□
b) visitors	□	□
c) nobody	□	□

14. Which of the following are regularly done in this house?

Vacuum mattress □

Wash bed linen at high temperature □

Uses of protective mattresses or pillow cover □

Dry clean furnishings □

Wash/dry-clean curtains □

Clean carpets □

15. Which of the following best describes how frequently do you

vacuum/mop/swept the floors?

Daily	□	Once/month	□
Few times /week	□	Less than once/month	□
Few times/month	□	Never	□

16. When did you last vacuum/mop/sweep the floor?

Within last week □ Within last 6 months □

Within last month □ Don’t vacuum □ Not applicable □

17. What type of stove do you use for cooking?

Gas □ Electric □ Both □

18. On average, how many times per week do you use your stove?

…………………………………………………. no. of times per week.

19. How long is an average cooking period?

……………………………………….length of cooking time.

20. How regularly do you use an extractor fan when cooking?

Always ◻ Never ◻

Sometimes ◻ No extractor fan installed ◻

21. Do you have problems with damp patches occurring inside the house?

Yes No

◻ ◻

22. Do you hang damp clothes anywhere inside the house?

Yes No

◻ ◻

23.Do you have problems with condensation occurring on windows inside the house? Yes No

◻ ◻

24. Are there any areas inside the house where mould appears frequently?

◻ Yes ◻ No go to Q26

25. In which rooms does mould appear frequently? …………………

26. How regularly do you use an extractor fan when having a bath or shower?

Always	◻	Never	◻
Sometimes	◻	No extractor fan install	◻

27. Do you have animals (inside)? Yes ◻ No ◻

If yes, please specify……………………………………….

28. What kind of floor coverings do you have?

	in child's bedroom	in living room
a) Carpet	◻	◻
b) Tiles	◻	◻
c) Linoleum	◻	◻
d) Concrete	◻	◻
e) Slate (stone)	◻	◻
f) Parquet	◻	◻
g) Other	◻	◻

28. During the last 3 months, have the following changes taken place?

	child's bedroom	living room
a) New carpeting	□	□
b) Walls painted	□	□
c) New furniture	□	□
d) New wall covering	□	□

30. Do you use special house cleaning materials? Yes □ No □

If yes, please specify…………………………………………

31. How would you describe the general ventilation?

	in child's bedroom	in living room
a) Very good	□	□
b) Good	□	□
c) Poor	□	□

Thank you for your assistance