INVESTIGATION OF MICRO-CLIMATIC FEATURES (VEGETATION) AFFECTING THE INDOOR AIR QUALITY IN SUBURB CITIES OF COLOMBO

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(Adm No:118772N)

Degree of Master of Engineering in Environment Engineering And Management

Department of Civil Engineering

University of Moratuwa
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DECLARATION OF THE CANDIDATE AND SUPERVISOR

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D.S.P.R.D.Premachandra Date

The above candidate has carried out research for the Masters under my supervision.

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Signature of the Supervisor: Date

Prof. (Mrs) C.Jayasinghe

Professor

Department of Civil Engineering

University of Moratuwa

ABSTRACT

Considerable number of studies show a favourable impact of vegetation and an adverse impact of synthetic built environment on urban micro-climates. Despite these findings, people eradicate these favourable micro-climatic features for built purposes. In the past few decades suburbs of the Colombo, the capital city of Sri Lanka, was subjected to a rapid development mainly for residential purposes. As a result, paddy fields, marshy lands and large tree canopies have been converted to a built environment with scattered green patches. This study was aimed at determination of the impact of micro-climatic features on air quality and thermal comfort.

Air quality investigations were carried out in five residential buildings which were selected based on the surrounding micro-climatic features. Indoor concentrations of CO_2, NO_2, $PM_{2.5}$, CO, VOC, temperature, relative humidity and wind speeds were measured during the day time from 9.00 AM to 4.00 PM in each sample building. The results were checked against the air quality standards and an attempt has been made to establish a relationship with micro-climatic features.

The results showed that the air quality in suburbs is still in the acceptable range except for peaking of $PM_{2.5}$ concentration beyond the threshold time to time. Lower levels of temperature and CO_2 concentration were observed with good micro-climatic features. Decrease of $PM_{2.5}$ concentration was also detected with the increase of distance to the main road and vegetation cover. These findings will benefit the township planning in terms of preserving the air quality and thermal comfort levels in suburbs.

***Key Words*: Indoor Air Quality, Micro-climate, Suburb, Thermal Comfort**

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LIST OF ABBREVIATIONS

Abbreviation	Description
AM	Ante Meridian
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
clo	Clothing insulation
COHb	Carbooxyhaemoglobin
CO	Carbon Monoxide
CO_2	Carbon Dioxide
EPA	Environmental Protection Agency
HVAC	Heating, ventilation, and air conditioning
IAQ	Indoor air quality
LEED	Leadership in Energy and Environmental Design
met	Metabolic Equivalent
NIOSH	National Institute for Occupational Safety and Health
NO_2	Nitrogen Dioxide
PM	Post Meridian
$PM_{2.5}$	Particulate Matter in diameter of 2.5 micrometer or smaller
PMV	Predicted Mean Vote
PPD	Predicted Percentage of Dissatisfied
ppm	Part Per Million
RH	Relative Humidity
UHI	Urban Heat Island
US EPA	United State Environmental Protection Agency
USGBC	United State Green Building Council
VOC	Volatile Organic Compound
WHO	World Health Organization

1. CHAPTER ONE: INTRODUCTION

1.1. BACKGROUND

Vegetation affects the micro-climate in terms of balancing the temperature, relative humidity and several air pollutant levels in the atmosphere. The increase of temperature in built environment relative to surrounding rural environment, which is termed as the urban heat island effect, is mainly caused by the trapped long-wave heat radiation which is emitted by the heated man-made structures. Vegetation reduces this long-wave radiation by lowering the temperature of the structure through shading. It converts the net radiation into latent heat other than the sensible heat through evapotranspiration. Conversely, water bodies also transform the solar radiation into latent heat through evaporation. Moreover, water bodies reflect a considerable fraction of short-wave radiation to the upper atmosphere. Thus vegetation and water bodies help to create a better micro-climate in the vicinity.

A number of both experimental and numerical studies has showed that the vegetation can lower the outdoor temperature and increase the thermal comfort in the urban areas. The presence of vegetation has also resulted in lowering the energy demand. It was found that the outdoor vegetation can reduce the levels of air pollutants by plant absorption and adsorption. Special attention has been paid to find the reduction in Carbon Dioxide (CO_2) concentration since vegetation utilizes CO_2 for photosynthesis. Despite these findings, people eradicate these favourable micro-climates for built purposes.

In the past few decades suburbs of the Colombo, the capital city of Sri Lanka, have been drawn the attraction for residential development. These suburbs which were once abandoned with large tree canopies have now been converted to built environment with scattered small green patches. With the attraction drawn to suburbs, the land prices have gone up rapidly persuading people to use maximum extent of their land for built purposes. Thus the paddy fields and the marshy lands which had an immense biodiversity have also been replaced with buildable lands. Moreover, the extent of the water bodies have downsized due to the lack of maintenance and less attention paid to the importance of these micro-climatic features in maintaining the air quality and thermal comfort.

This study is designed to find out the current status of the suburbs with respect to air quality and thermal comfort since the rapid urbanization can increase the level of air pollutants and temperature. The effect of several micro-climatic features has also been studied to suggest some remedial measures.

1.2. RESEARCH PROBLEM

During the last few decades, people have experienced the regular reduction of thermal comfort and detoriation of air quality in their surrounding environment. At present most of the occupants living in cities and suburbs are suffering from thermal discomfort and sick building syndrome.

At first glance it seems to be happening due to the climatic changes. However by deep analyzing it can be proved that it is caused due to the destroying of the natural environment by human activities. Because of modernization, the natural world has faced a threat. People have failed to notice that the surrounding microclimate gives more benefits to them in terms of thermal comfort and air quality. Green barriers will filter the thermal radiations, air-borne pollutants as well as reduce greenhouse gas emissions. Unless people manage to stop the rapid destruction of the green areas, there will be trouble in surviving in a polluted environment in future.

1.3. OBJECTIVES

The main objectives of this study are;

- To evaluate the air quality in suburban residential buildings.
- To study the effect of micro-climatic features (vegetation) on indoor air quality.
- To suggest measures for controlling the high concentrated air quality contaminants.

1.4. SIGNIFICANCE OF STUDY

The results of this study will provide some insights and information on present suburbs air quality levels with permissible levels of pollutants comparatively. Further it will show how to improve the effects of thermal discomfort and depreciated air quality with the presence of better micro climatic features.

The research is concentrate only on the indoor air quality and thermal comfort due to micro climatic condition of a house and its surround in suburb area. However these conditions could be influenced by many other factors in the surrounding environment such as situation of forest or natural water body within the area, level of urbanization such as construction of Roads, buildings etc., change of the life style such as vehicular density, their movement intensity etc. And the types of trees are also not analyzed in this study. It is considered that all types of trees contribute in similar weight to the environment for thermal satisfaction and air borne pollutant reduction. On the other hand global climatic condition influences in macro manner could not be account to this research.

2. CHAPTER TWO: LITERATURE REVIEW

2.1. Urban heat island

An urban heat island (UHI) is a city that is significantly warmer than its surrounding rural areas due to human activities. It is mainly caused from the modification of land surfaces, which use materials that effectively store short-wave radiation [1]. Waste heat generated by energy usage is a secondary contributor for making a heat island [2]. With the increase in the population density focusing from city centre, the affected land area will expand and increase the average temperature. The heat island refers to any area, whether populated or not, which is consistently hotter than the surrounding area.

2.1.1. Causes for Urban Heat Island Effect

Urban heat island effect is caused due to several reasons. The principal reason for the night time warming is that the short-wave radiation is still within the concrete, asphalt, and buildings that was absorbed during the day, unlike suburban and rural areas. This energy is then slowly released during the night as long-wave radiation, making cooling a slow process [1]. Two other reasons are changes in the thermal properties of surface materials and lack of evapotranspiration due to lack of vegetation in urban areas. With a decreased amount of vegetation, cities also lose the shade and cooling effect of trees, the low albedo of their leaves, and the removal of carbon dioxide [3]. Materials commonly used in urban areas for pavement and roofs, such as concrete and asphalt, have significantly different thermal bulk and surface radiative properties than the surrounding rural areas. This causes a change in the energy balance of the urban area, often leading to higher temperatures than surrounding rural areas [4].

Geometric effects are also a cause for the urban heat island. Because tall buildings in urban areas have multiple surfaces for the reflection and absorption of sunlight, they increase the efficiency of heating the urban areas. This is known as "urban canyon effect" [5]. Another effect of buildings is the blocking of wind, which also inhibits cooling by convection and pollution from dissipating. Waste heat from automobiles, air conditioners, industry, and other sources also contribute to the urban heat island [2]. High levels of pollution in urban areas can also increase the urban heat island, as many forms of pollution change the radiative properties of the atmosphere [4].

A comparison of the following images shows that where vegetation is dense, temperatures are lower.

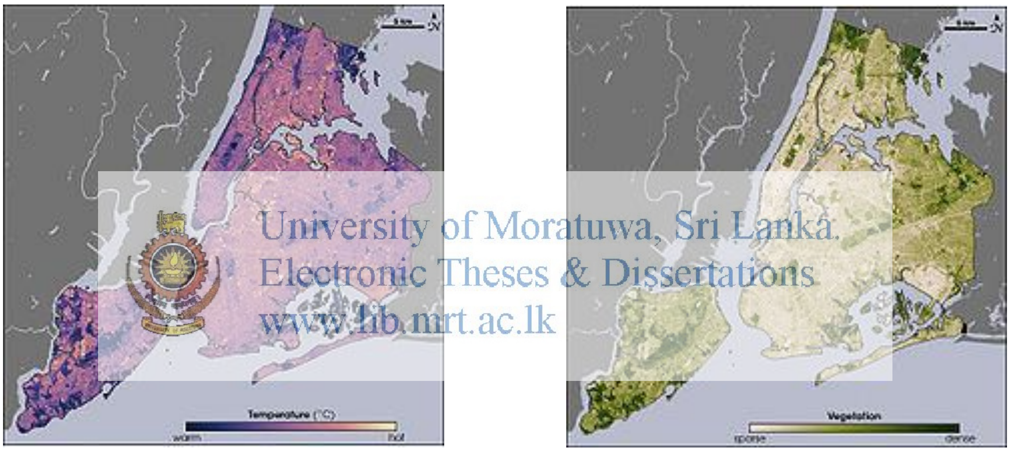


Figure 2-1: Thermal (left) and vegetation (right) locations around New York City via infrared satellite imagery.

2.1.2. Impact on species

Some animals are colonized better with the conditions of urban heat islands. Ant colonies and flies colonies in urban heat islands have increased the colonized behaviour outside of their normal range. Some species, example Grey-headed Flying Fox (Pteropus Poliocephalus) and the Common House Gecko, can utilize the conditions provided by urban heat islands to improve their breeding strategies [6].

Grey-headed Flying Fox, found in Melbourne Australia, has colonized urban habitats following the increase in temperatures there [6].

With hot climates, urban heat islands will extend the growing season, therefore altering the breeding strategies of inhabiting species [7]. This can be seen best in the effects that urban heat islands have on water temperature [7]. As temperature of the nearby buildings has increased, surface air temperature will increase and precipitation will warm rapidly. This causes excessive thermal pollution to the water bodies due to the warm, rapid runoff. The increase in the thermal pollution has the ability to increase water temperature by 20 to 30 degrees [8]. This increase will cause the fish species inhabiting the body of water to undergo thermal stress and shock due to the rapid change in temperature to their climate [8].

Within urban habitats, insects are more abundant than in rural areas. Normally insects control their body temperature relevant to the environment temperature, called as Ectotherms. Insects prefer warmer climates to thrive. A study done in Raleigh, North Carolina, conducted on Parthenolecanium quercifex (oak scales), showed that this particular species preferred warmer climates and was therefore found in higher abundance in the urban habitats than on oak trees in rural habitats. Over time of living in urban habitats, they have adapted to thrive in warmer climates than in cooler [9].

Some non-native species like more to living in human activity areas. For example, populations of cliff swallows prefer to make their nests under the eaves of homes in urban habitats. They make their homes using the shelter provided by the humans. It has given them the protection and reduced the threat of predators.

2.1.3. Impacts on weather and climate

Urban heat island is directly affected to the local meteorology. It includes the altering of local wind patterns, the development of clouds and fog, the humidity, and the rates of precipitation. The extra heat created in the urban heat island can induce additional showers and thunderstorm activity. In addition, the urban heat island creates during the day a local low pressure area where relatively moist air from its rural surroundings converges, possibly leading to more favorable conditions for cloud formation [10]. It increases the rainfall rates in downwind of cities. Some cities show a total precipitation increase by 50%.

2.1.4. Health effects

Urban heat island has directly influenced the health and welfare of urban residents. Within the United States alone, an average of 1,000 people die each year due to extreme heat [11]. With the increasing of the temperature of a city, it results in increase of the magnitude and duration of heat waves within the city. Research has found that the mortality rate during a heat wave increases exponentially with the maximum temperature [11], an effect that is intensifying by the urban heat island.

Increased temperatures have been reported to cause heat stroke, heat exhaustion, heat syncope, and heat cramps [12]. Some studies have also looked at how severe heat stroke can lead to permanent damage to organ systems [12]. This damage can increase the risk of early mortality because the damage can cause severe impairment in organ function [12]. Other complications of heat stroke include respiratory distress syndrome in adults and disseminated intravascular coagulation [13]. Some researchers have noted that any compromise to the human body's ability to thermoregulate would in theory increase risk of mortality [12]. This includes illnesses that may affect a person's mobility, awareness, or behavior [12]. Researchers have noted that individuals with cognitive health issues (e.g. depression, dementia, Parkinson's disease) are more at risk when faced with high temperatures and "need to take extra care" as cognitive performance has been shown to be differentially affected by heat [12][13]. People with diabetes, are overweight, have sleep deprivation, or have cardiovascular/cerebrovascular conditions should avoid too much heat exposure [12][13]. Some common medications that take for thermoregulation can also increase the risk of mortality. Specific examples include anticholinergics, diuretics, phenotiazines and barbiturates [12][13]. Not only health, but heat can also affect behavior. A United State study suggests that heat can make people more irritable and aggressive, noting that violent crimes increased by 4.58 out of 100,000 for every one-degree increase in temperature [14].

A researcher found that high urban heat island intensity correlates with increased concentrations of air pollutants that gathered at night, which can affect the next day's air quality [14]. These pollutants include volatile organic compounds, carbon monoxide, nitrogen oxides, and particulate matter [13]. The production of these pollutants combined with the higher temperatures in UHIs can quicken the production of ozone [14]. Ozone at surface level is considered to be a harmful pollutant. Studies suggest that increased temperatures in UHIs can not only increase polluted days, but also that other factors (e.g. air pressure, cloud cover, wind speed) can also have an effect on pollution [14].

There are some studies show that the possibility of health impact from urban heat island effect is not proportionate because of its uneven distribution based on various factors such as age, ethnicity and socioeconomic status [13]. Therefore this raises the possibility of health impacts from urban heat island being an environmental justice issue.

2.1.5. Impact on nearby water bodies

Urban heat island effects also reduce the water quality. Hot pavement and rooftop surfaces transfer their excess heat to storm water, and then drains into storm sewers and raises water temperatures. This temperature is released into streams, rivers, ponds, and lakes. Additionally, increased urban water body temperatures lead to decrease the diversity in the water. In August 2001, rains over Cedar Rapids, Iowa led to a 10.5C (18.9F) rise in the nearby stream within one hour, which led to fish dying [15]. Since the temperature of the rain was comparatively cool, it could be attributed to the hot pavement of the city [16]. Rapid temperature changes can be stressful to aquatic ecosystems. Permeable pavements may mitigate these effects by percolating water through the pavement into subsurface storage areas where it can dissipate through absorption and evaporation [17].

2.1.6. Impact due to tree canopy cover

Tree canopies have considerable effect to the urban heat island effect because they reduce air temperatures by 10 degrees, and surface temperatures by up to 20-45 degrees [18][19]. The land cover with urban heat island effect contains different range of temperature variation because poor people do not have the financial resources to plant and maintain trees and wealthy people can afford more trees, on both public and private property.

2.1.7. Impact on energy usage

The energy usage becomes higher with the effect of urban heat islands. It has increased energy required for air conditioning and refrigeration in cities that are in comparatively hot climates. The Heat Island Group estimates that the heat island effect costs in Los Angeles about US$ 100 million per year in energy [20]. Conversely, those that are in cold climates would have less demand for heating. However, through the implementation of heat island reduction strategies, the net energy can be saved significantly.

2.1.8. Mitigation

The temperature difference between urban areas and the surrounding suburban or rural areas are normally around 5 °C and nearly 40 percent of that increase is due to the existence of dark roofs and dark-colored pavement [21]. The heat island effect can be reduced slightly by using white or reflective materials to build houses, roofs, pavements, and roads, thus increasing the overall albedo, reflecting power of a surface, of the city [21]. A cool roof made from a reflective material such as vinyl reflects at least 75 percent of the sun's rays, and emit at least 70 percent of the solar radiation absorbed by the building envelope. Asphalt built-up roofs (BUR), by comparison, reflect 6 percent to 26 percent of solar radiation [22].

Light-colored concrete has reflected capacity up to 50% more light than asphalt and reducing ambient temperature [18]. Black asphalt has a low albedo value, absorbs a large percentage of solar heat and create warmer environment. However, research into the interaction between reflective pavements and buildings has found that, unless the nearby buildings are fitted with reflective glass, solar radiation reflected off light-colored pavements can increase building temperatures and increase the air conditioning demands [23].

By increasing the amount of vegetation, environmental temperature can be minimized. Green roofs are excellent insulators during the warm weather months and the plants cool the surrounding environment. Air quality is improved as the plants absorb carbon dioxide parallel with production of oxygen. The city of New York determined that the cooling potential per area was highest for street trees, rooftops, light covered surface, and open space planting [24].

A hypothetical "cool communities" program in Los Angeles has projected that urban temperatures could be reduced by approximately 3 °C after planting ten million trees, reroofing five million homes, and painting one-quarter of the roads at an estimated cost of US$1 billion, giving estimated annual benefits of US$170 million from reduced air-conditioning costs and US$360 million in smog related health savings [25].

2.1.9. Mitigation strategies

a) White roofs

Painting rooftops white has become a common strategy to reduce the heat island effect [26]. In cities, there are many dark colored surfaces that absorb the heat of the sun in turn lowering the albedo of the city [26]. White rooftops allow high solar reflectance and high solar emittance, increasing the albedo of the city or area the effect is occurring [26].

b) Green roofs

Green roofs are another method of decreasing the urban heat island effect. Green roof is the practice of having vegetation on a roof; such as having trees or a garden. The plants that are on the roof increase the albedo and decrease the urban heat island effect [26].

c) Planting trees in cities

Planting trees around the city can be another way of increasing albedo and decreasing the urban heat island effect. Trees absorb carbon dioxide, add oxygen to the air and provide a shade. It also gives nice visuals to visitors.

d) Green building programs

Conducting the green building programs is one of the best ways of mitigation from the heat island effect. It is conducted under the supervision of Green Building Councils. In Sri Lanka it is conducted by Green Building Council of Sri Lanka (GBCSL). Certification for Leadership in Energy and Environmental Design (LEED) has been given by US Green Building Council. Green Building Rating System is used to quantify the impact on nature by reducing heat islands, minimizing impacts on microclimates and human and wildlife habitats. Credits add for reflective roofing or planted roofs to achieve LEED certification. Buildings also receive credits by providing shade. The Green building Program has awarded points to sites that take measures to decrease a building's energy consumption and reduce the heat island effect. More credit points can be received to the sites with roof coverage from vegetation, highly reflective materials, or a combination of the two.

2.1.10. Co-benefits of mitigation strategies

a) Trees and green gardens enhance the mental health of people

Many people living in the urban areas do not have forests or thick green covered areas but they have access to parks and green gardens in their areas. Sometimes it may be the only connection that they have with nature. A study shows that having contact with nature helps promote our health and well-being. People who had access to gardens or parks were found to be healthier than those who did not [27]. Another study was done to investigate whether or not the viewing of natural scenery may influence the recovery of people after undergoing surgeries and found that people in hospitals who had a window with a scenic view had not disappointed or negative comments [28].

b) Tree planting as empowerment and community building

Besides the gaining of money for their plantation, tree planting people have an opportunity to come together, build capacity, community pride and the opportunity to collaborate and network with each other. It has caused to improve their living status.

c) Green roofs as food production

Today food scarcity is the burning issue in the world. Lands available for food production is limiting day to day with growing population. Growing food on rooftops is one of the best options for fast growing communities in the urbanized city.

d) Green roofs and biodiversity of the species

Green roofs are important for some species because they allow organisms to inhabit the new garden. When maximizing the opportunities provided to the species to attract to a green roof, the diversity of the garden becomes wider. By planting a wide array of plants, different kinds of invertebrate species will be able to colonize, they will be provided with foraging sources and habitat opportunities [29].

e) Urban forests and a cleaner atmosphere

Trees provide many benefits to the surrounding environment such as absorbing carbon dioxide, and other pollutants. Also they provide shade and reduce ozone emissions from vehicles. By having many trees, we can cool the city heat by approximately 10 degrees to 20 degrees, which will help reducing ozone and helping communities that are mostly affected by the effects of climate change and urban heat islands [30].

2.2. Microclimate

A microclimate is a local atmospheric climate zone where the climate of the zone clearly differs from the climate of surrounding area. It may be warmer or colder, wetter or drier. The micro climatic areas can be defined as small as a few square feet as a home garden or as large as many square meters.

Microclimates can be found in most places. Microclimates exist near the water bodies which may cool the local atmosphere, or in heavily urban areas where brick, concrete, and asphalt absorb the sun's energy, heat up, and reradiate that heat to the ambient air, the resulting urban heat island is a kind of microclimate. Microclimate can occur around the artificially modified ground which is made out of tar or concrete, because these are man made objects, they do not take in much heat, they mainly reradiate it.

Temperature and humidity are the main parameters to define a microclimate within a certain area [31].

2.2.1. Advantages of Microclimate

The microclimate in an artificially developed industrial park may vary greatly from a greenery natural park. Flora in natural parks absorbs light and heat with their leaves. In contrast a building or parking lot in developed industrial parks heat radiates back into the air. To reduce the unnecessary heating, the wide spread solar energy can be collected to mitigate overheating of urban environments, and it can be put to necessary work instead of heating the foreign surface objects.

A small growing region of crops makes separate microclimatic area that cannot thrive in the broader area; this concept is often used in agricultural practice. Microclimates can be used to the advantage of gardeners who carefully choose and position their plants.

Tall buildings create their own microclimate, both by overshadowing large areas and by channeling strong winds to ground level. Wind effects around tall buildings can be assessed as part of a microclimate study.

Microclimates can be created purposely by making changes to separate parts of the environments, such as those in a room or other enclosure. It adds more positive benefits to the user. Microclimates are commonly created and carefully maintained in reputed and valuable places in the city such as museums and ancient places. This can be done using passive methods such as with active microclimate control devices or using silica gel.

2.2.2. Influences on microclimate

a) Vegetation

Vegetation adds more benefits to the environment as it prevents heat loss and radiation, regulates the temperature of the soil, filters dust and other particles from the air and can act as a windbreak or suntrap. Vegetation is naturally adapted to suit the natural environment to make a better micro climate [32]. Plants in tropical countries consist of dark, broad leaves to allow maximum absorption of sunlight and effective transpiration of moisture back into the air. It influences the microclimate in the immediate vicinity.

b) Soil

The composition of the soil in an area has affected the microclimates. How much water retains or evaporates from the ground depends on the soil composition. For example, soils heavy in clay can act like a pavement, moderating the near ground temperature. On the other hand; if the soil has many air pockets, then the heat could be trapped underneath the topsoil, resulting in the increased possibility of frost at the ground level [33].

Other than the mineral composition of the soil, the degree of coverage affects the temperature and moisture evaporation. Bare soils reflect more light and heat than soil that is covered with vegetation.

c) Water

It is not only the moisture level within the soil, but the water stored on the surface of the land also influences the microclimate. The presence of a large lake or a reservoir within the region or the presence of a smaller pond or a stream within the garden will create a moderate climate in the area. This is caused due to the fact that water gains and loses heat more slowly than land.

The water bodies add the moisture to the air through evaporation. This atmospheric moisture captures heat from the sun and makes the surrounding air warmer.

d) Topography

The shape of the land has also been found to be influence the microclimate. A microclimatic influenced topographical feature is slope of the ground. The amount of solar radiation received depends on the direction of slope. It also impacts on the temperature and shading of the area.

Small dips and indentations on the ground surface can affect the microclimate. It forms a collection point for cold air and forms small forest pockets.

The angle of slope is also a major factor to determine the influence of wind and water on the site. If the land has a steep slope it creates a lot of wind and impacts the vegetation on the windward side. It also creates turbulence on the leeward side of the slope as the wind falls back down on the other side of the slope [34]. In terms of water, it runs off more quickly in a steeper slope. It has less time to percolate into the soil and affect the vegetation in that area. And it causes soil erosion on the slope.

e) Artificial Structures

Buildings constructed on a land impact the microclimate by absorbing heat during the daytime and releasing it at night, deflecting wind, creating sheltered spots and reflecting sunlight. Some artificial structures also modify the microclimate. Courtyards and other paved surfaces like driveways, moderate the temperature by absorbing and releasing heat, while fences and walls can give plants protection, shade and shelter from wind. Even by placing rock judiciously in the garden has changed the surrounding microclimate by storing and releasing heat.

2.3. Thermal Comfort

Thermal comfort is the condition of mind that feels and expresses satisfaction with the thermal environment. Thermal comfort level can be assessed by evaluating the situation according to the ANSI/ASHRAE Standard 55 [35]. Maintaining the favorable level of thermal comfort for occupants of buildings or other enclosures is one of the main objectives of HVAC (heating, ventilation, and air conditioning) design engineers.

Normally heat generates by human metabolism. When allowed to dissipate the heat generated by human metabolism with thermal equilibrium of surrounding environment, thermal neutrality can be maintained. The main factors that influence thermal comfort are those that determine heat gain and loss, namely metabolic rate, clothing insulation, air temperature, mean radiant temperature, air speed and relative humidity. Occupants control their thermal environment by means of clothing, operable windows, fans, personal heaters, and sun shades [36]. Psychological parameters such as individual expectations also affect thermal comfort [36].

Thermal comfort levels can be calculated by the Predicted Mean Vote (PMV) model and the adaptive model. The PMV model can be applied to air conditioned buildings, while the adaptive model can be generally applied only to buildings where no mechanical systems have been installed [35].

Similar to ASHRAE Standard 55 there are other comfort standards like EN 15251 [37] and the ISO 7730 standard [38].

2.3.1. Significance of thermal comfort

Working in more favorable thermal comfort environment has caused to increase the productivity and health of the workers. A research found that office workers who are satisfied with their thermal environment are more productive [39]. Because of the thermal discomfort people show sick building syndrome symptoms. The environment that has combination of high temperature and high relative humidity reduces the thermal comfort and indoor air quality [40].

Although a single static temperature can be comfortable, thermal delight is usually caused by varying thermal sensations. Many varying indoor conditions occur in naturally ventilated buildings. These buildings can save energy and create a more satisfied environment to the occupants [36].

2.3.2. Factors influencing thermal comfort

Thermal satisfaction from person to person has deferred from large variation. It is difficult to find an optimal temperature for everyone in a given space. Laboratory and field data have been collected to define conditions that will be found comfortable for a specified percentage of occupants [35].

There are six factors that affect the thermal comfort. Some of these factors directly affect the occupants (Personal factors) and others are influencing the conditions of the thermal environment (environmental factors). Personal factors are the metabolic rate and clothing level of insulation. Environmental factors are air temperature, mean radiant temperature, air speed and humidity.

a) Metabolic rate

People have different metabolic rates that can fluctuate due to activity level and environmental conditions [41]. According to the ASHRAE 55-2010 Standard, metabolic rate can be defined as the level of transformation of chemical energy into heat and mechanical work by metabolic activities within an organism. Metabolic rate is expressed in met units, which are defined as follows:

1 met = 58.2 W/m² (18.4 Btu/h·ft²), which is equal to the energy produced per unit surface area of an average person seated at rest. The surface area of an average person is 1.8 m² (19 ft²) [35].

ASHRAE Standard 55 provides a table of met rates for a variety of activities. Some common values are 0.7 met for sleeping, 1.0 met for a seated and quiet position, 1.2-1.4 met for light activities standing, 2.0 met or more for activities that involve movement, walking, lifting heavy loads or operating machinery. For intermittent activity, the Standard states that is permissible to use a time-weighted average metabolic rate if individuals are performing activities that vary over a period of one hour or less. For longer periods, different metabolic rates must be considered [35].

According to ASHRAE Handbook of Fundamentals, it is complex to estimate metabolic rate. If the metabolic rate exceeds 2 or 3 met by performing various physical activities the accuracy is low. Therefore, the Standard is not applicable for activities with an average level higher than 2 met. Met values can be calculated more accurately than the tabulated values in the ASHRAE standard 55 using an empirical equation that is considered the rate of respiratory oxygen consumption and carbon dioxide production.

Food and drink habits may have an influence on metabolic rates, which indirectly influences thermal preferences. These effects may change depending on food and drink intake [42]. Body shape is another factor that affects thermal comfort. Heat dissipation depends on body surface area. A tall and skinny person has a larger surface-to-volume ratio, can dissipate heat more easily, and can tolerate higher temperatures more than a person with a rounded body shape [42].

b) Clothing insulation

The type and amount of clothing worn by a person has directly affected the thermal comfort of that person. Thermal insulation worn by a person has influenced the heat loss and consequently the thermal balance of the person. Thickness of the garment, layers of insulating clothing and type of material of the garment have helped to keep a person warm or lead to overheating. Air movement through the cloth and relative humidity can decrease the insulating ability of the material.

1 clo is equal to 0.155 $m^2 \cdot K/W$ (0.88 $°F \cdot ft^2 \cdot h/Btu$). This corresponds to the clothing insulation value of a person who wearing a trouser, a long sleeved shirt, and a jacket. Clothing insulation values for other common garments can be found in ASHRAE 55 [35].

c) Air temperature

The average temperature of the air surrounding the occupant, with respect to location and time is defined as air temperature. According to ASHRAE 55 standard, the spatial average takes into account the ankle, waist and head levels, which vary for seated or standing occupants. The temporal average is based on three-minute intervals with at least 18 equally spaced points in time. Air temperature is measured by a reading of a dry bulb thermometer.

d) Mean radiant temperature

The amount of radiant heat transferred from a surface is the radiant temperature. It depends on the material's ability to absorb or emit heat, called as emissivity. The mean radiant temperature, depends on the temperatures and emissivity of the surrounding surfaces. As well as the amount of the surface that is seen by the object, called as the view factor, has also influenced the mean radiant temperature.

e) Operative temperature

Operative temperature gives the combine effect due to air temperature and mean radiant temperature. It is often approximated as the average of the air dry-bulb temperature and of the mean radiant temperature at the given place in a room. Sometimes the operative temperature can be simplified as only the air temperature when the building has low thermal mass.

f) Air speed

Air speed is defined as the rate of air movement at a point, without regard to direction. According to ANSI/ASHRAE Standard 55, it is the average speed of the air to which the body is exposed, with respect to location and time. Normally Air speed is not uniform. Some places have strong non-uniform velocity field and consequently change the skin heat losses. Therefore, the designer shall decide the proper averaging, especially including air speeds incident on unclothed body parts that have greater cooling effect and the potential for local discomfort [35].

g) Relative humidity

Relative humidity is the ratio of the partial pressure of water vapor to the equilibrium vapor pressure of water at the same temperature. Relative humidity depends on temperature and the pressure of the system of interest. Sweating is an effective heat loss mechanism of the skin. It measures the evaporation level from the skin. At high RH, the air contains a higher amount of water vapor and therefore evaporation from the skin is low. Therefore heat loss is decreased. On the other hand, very dry environments are also uncomfortable because of the higher level of sweating. The recommended level of indoor humidity is in the range of 30-60% in air conditioned buildings [43].

Relative temperature can be calculated by measuring the difference between the readings of wet-bulb thermometer and dry-bulb thermometer. The wet-bulb reading always shows a slightly lower temperature than the dry bulb one. The larger the temperature differences between the two thermometers, the lower the level of relative humidity.

The wetness of skin in different part of the body affects the perceived thermal comfort. Thermal comfort limits for skin wetness differ in locations of the body. The extreme points are more sensitive to thermal discomfort. Humidity can also increase the wetness on the body.

Recently, the effects of low relative humidity and high air velocity were tested on humans after bathing. Researchers found that low relative humidity engendered thermal discomfort as well as the sensation of dryness and itching. It is recommended to keep relative humidity levels higher in a bathroom than other rooms in the house for optimal conditions [44].

2.3.3. Thermal comfort models

There are two main different models for thermal comfort as the static model (PMV/PPD) and the adaptive model.

a) PMV/PPD method

This model was developed by *P. O. Fanger* using heat balance equations and empirical studies about skin temperature to define the comfort. For the model, survey for standard thermal comfort can be carried out by the thermal sensation on a seven point scale from cold (-3) to hot (+3). Using the Fanger's equations, a value for the Predicted Mean Vote (PMV) can be calculated and the calculations are based on the factors considering the air temperature, mean radiant temperature, relative humidity, air speed, metabolic rate, and clothing insulation. Zero is the ideal value, representing thermal neutrality, and the comfort zone is defined by the combinations of the six parameters for which the PMV is within the recommended limits ($-0.5<PMV<+0.5$) [35]. It predicts the thermal sensation of a population by determining what conditions are comfortable. It is more useful to consider whether or not people will be satisfied. For that reason Fanger developed another equation to relate the PMV to the Predicted Percentage of Dissatisfied (PPD).

This method treats all occupants the same and disregards location and adaptation to the thermal environment [45]. It is basically considered that the indoor temperature does not change seasonally and defines one average constant temperature throughout the year round. This is taking a more passive stand that humans do not have to adapt to different temperatures since it will always be constant [46].

ASHRAE Standard 55-2010 uses the PMV model to set the requirements for indoor thermal conditions. It requires that at least 80% of the occupants be satisfied [35].

The CBE Thermal Comfort Tool for ASHRAE 55 allows users to input the six comfort parameters to determine whether a certain combination complies with ASHRAE 55. The results are displayed on a psychrometric or a temperature-relative humidity chart and indicate the ranges of temperature and relative humidity that will be comfortable with the given the values input for the remaining four parameters [47].

b) Adaptive comfort model

The adaptive model was developed on the concept that outdoor climate influences indoor comfort because humans can adapt to different temperatures during different times of the year. The adaptive hypothesis predicts that contextual factors, such as having access to environmental controls, and past thermal history influence building occupants' thermal expectations and preferences [36]. There were past field studies conducted worldwide to study about the thermal comfort of building occupants and the results shows that occupants in naturally ventilated buildings can accept and prefer wide range of temperature variations than the occupants in air conditioned buildings because their preferred temperature depends on outdoor conditions [36]. These results were incorporated in the ASHRAE 55-2004 standard as the adaptive comfort model. The adaptive chart relates indoor comfort temperature to prevailing outdoor temperature and defines zones of 80% and 90% satisfaction [35].

The ASHRAE-55 2010 Standard has introduced the prevailing mean outdoor temperature as the input variable for the adaptive model. Prevailing mean outdoor temperature is calculated by the arithmetic average of the mean daily outdoor temperatures over 7 to 30 sequential days prior to the day in question [35]. In order to apply the adaptive model, there should be no mechanical cooling system for the space, occupants should be engaged in sedentary activities with metabolic rates of 1-1.3 met, and a prevailing mean temperature greater than 10 °C (50 °F) and less than 33.5 °C (92.3 °F) [35].

This model applies to the naturally ventilated place that outdoor climate directly influences the indoor condition and so the comfort level. In fact, studies by de Dear and Brager showed that occupants in naturally ventilated buildings were tolerant of a wider range of temperatures [36]. ASHRAE Standard 55-2010 states that differences in recent thermal experiences, changes in clothing, availability of control options and shifts in occupant expectations can change people's thermal responses [35].

There are other standards for thermal comfort such as European EN 15251 and ISO 7730 standard. Although ASHRAE 55 adaptive standard was only used for naturally ventilated buildings, EN 15251 can be applied to mixed-mode buildings provided the system is not running [37].

2.3.4. Effects of natural ventilation on thermal comfort

Some buildings have used air conditioning system to control the thermal environment while other buildings have natural ventilation systems. If a building is properly designed for natural ventilation, opening doors and windows is enough for keeping indoor conditions within the range. For the extremes, people can use fans in the summer and wear extra jackets in the winter to keep thermal comfort. When we compare the natural ventilated system with the mechanical system the natural system can drastically reduce the energy consumption.

2.3.5. Thermal sensitivity

Sometimes, quantified thermal sensitivity feel to a group of individuals takes higher values with lower tolerance to non-ideal thermal conditions. This group includes pregnant women, the disabled, as well as individuals whose age is below fourteen or above sixty, which is considered the adult range [48]. Existing literature provides consistent evidence that sensitivity to hot and cold surfaces declines with the age of people. There is also some evidence of a gradual reduction in the effectiveness of the body in thermoregulation after the age of sixty [48]. This is mainly due to a more sluggish response of the counteraction mechanisms in lower part of the body that are used to maintain the core temperature of the body at ideal values [48].

2.3.6. Thermal stress

The thermal satisfaction or dissatisfaction is directly related to the thermal stress. It may be influenced due to impact of strong solar radiation, air movement or humidity. For example, thermal stress has occurred in a person who undergoes the training exercise or athletes during competitive events. Thermal stress values are expressed as the Wet Bulb Globe Temperature or Discomfort Index [49]. Normally, occupants cannot perform well under thermal stress. It was found that people's performance under thermal stress is about 11% lower than their performance at normal thermal conditions [49]. As well thermal stress in performing the work depends on the type of task that needs to be completed. Thermal heat stress can be physiologically identified by increasing blood flow to the skin and sweating.

2.4. Indoor Air Quality

Indoor air quality (IAQ) can be defined as the quality of air within the building or structure. It is related to the health and comfort level of the occupants inside. IAQ can be affected by several gases such as carbon monoxide, radon, volatile organic compounds, particulate matters, microbial contaminants as bacteria or any mass that can induce adverse health conditions. Diluting these contaminants by the proper ventilation system has improved the air quality level inside the building. As well methods of source controlling and filtration are used to improve the air quality. Frequent cleaning of the building is important to maintain the inside air quality of the building. Environmental Protection Agency (EPA) has guidelines for frequency of cleaning based on traffic, number of household members, pets, children and smokers. Carpets and rugs act as an air filter and must be cleaned frequently.

Determination of IAQ involves the collection of air samples, monitoring human exposure to pollutants, collection of samples on building surfaces, and computer modeling of air flow inside buildings.

Indoor air pollution in developing nations is the main burning issue at present. A major source of indoor air pollution in developing countries is the burning of biomass (e.g. wood, charcoal, dung, or crop residue) for heating and cooking [50]. The resulting exposure to high levels of particulate matter resulted in between 1.5 million and 2 million deaths in 2000 [51].

2.4.1. Common air pollutants

a) Passive smoke

Passive smoke is a type of tobacco smoking that affects the people in the surrounding environment of active smokers. It contains carbon monoxide gas and very small particulate matters (at $PM_{2.5}$ size) leads to create the problems in lungs. The only method to improve indoor air quality as regards the passive smoke is the implementation of comprehensive smoke-free laws.

b) Radon

Radon is colorless, odorless, tasteless, radioactive atomic gas, formed due to the radioactive decay of radium. It is found in rock formations beneath buildings or in certain building materials themselves. Radon is hazardous indoor gas, which causes lung cancer [52]. Radon gas enters buildings as a soil gas. It is accumulated at the bottom level of the building because it is a heavy gas. Also it can become into the building through water from bathroom showers. Building materials such as stone or tile products are a rare source of radon. The proper ventilation has a greater effect to reduce the amount of Radon. The hazard will be greatly reduced within a few weeks because the lifetime of Radon is short. Radon mitigation methods include sealing concrete slab floors, basement foundations, water drainage systems, or by increasing ventilation [53].

c) Molds and other allergens

Mold is always associated with moisture, and its growth can be inhibited by keeping humidity levels below 50% [54]. Water penetration into the building from leaks of plumbing, condensation due to improper ventilation, ground moisture penetration has caused to initiate the molds. Moisture is major reason for mold colonies forming. When mold mildew propagates by failure of drying out from wetted surface within several days, they release allergenic spores into the air. The varieties of molds contain several toxic compounds called mycotoxins. Exposure to hazardous levels of mycotoxin caused many health issues; mainly they lead to make the allergenic symptoms in a person who is already suffering from asthma.

d) Carbon monoxide

Carbon monoxide (CO) is a colourless, odourless gas that forms as a byproduct of incomplete combustion of fossil fuels. Common sources of carbon monoxide are tobacco smoke and automobile exhaust. This is one of the most acutely toxic indoor air contaminants. High levels of carbon monoxide can depreciate the oxygen supply to the brain and lead to nausea, unconsciousness and death.

e) Volatile organic compounds

Volatile organic compounds (VOCs) are emitted from certain solids or liquids as varieties of chemical compounds which cause adverse health effects. It is emitted by a form of gas. Studies have found that levels of several organics average 2 to 5 times higher indoors than outdoors [55]. VOCs are emitted by many products used for indoor activities including paints, varnishes and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, office equipment such as copiers and printers, correction fluids and carbonless copy paper, graphics and craft materials including glues and adhesives, permanent markers, and photographic solutions. All of these products can release organic compounds during usage, and, to some degree, when they are stored [55].

Chlorinated drinking water releases chloroform when hot water is used in the home. Benzene is emitted from fuel stored in attached garages. Overheated cooking oils emit acrolein and formaldehyde [55].

During the last decades, several steps have been taken to reduce indoor air contamination by limiting VOC emissions from products. These new products changed the marketplace where an increasing number of low-emitting products have become available during the recent years.

f) Asbestos fibers

Asbestos is a common building material mainly used for roofing or ceiling material. It is also present in some floor tiles, shingles, fireproofing, heating systems, pipe wrap, taping muds, mastics and other insulation materials. Normally, significant releases of asbestos fiber do not occur unless the building materials are disturbed, such as by cutting, sanding, drilling, or building remodeling. The asbestos also contains fiber materials can be spread into the air during the removal process. A management program for asbestos-containing materials is very important to maintain the air quality.

When asbestos-containing material is damaged or disintegrates, microscopic fibers are dispersed into the air. Inhalation of asbestos fibers over long exposure times is a cause for lung cancer. The symptoms appear after 20 to 30 years of the first exposure to asbestos.

Some countries and states have set the standards for acceptable levels of asbestos fibers in indoor air. There are particularly stringent regulations applicable to schools.

g) Carbon dioxide

Carbon dioxide (CO_2) is the main indoor pollutant emitted by humans through human metabolic activity. Occupants in the buildings are the main indoor source of carbon dioxide in the buildings. Unusual high indoor Carbon dioxide levels may cause occupants to grow drowsy, to get headaches, or to function at lower activity levels. Indoor CO_2 level is the best indicator to know the adequacy of outdoor air ventilation relative to indoor occupant density and metabolic activity.

Normally the total indoor and outdoor CO_2 level difference should be maintained less than 600 ppm to feel comfortable and satisfied. The National Institute for Occupational Safety and Health (NIOSH) considers that indoor air concentrations of carbon dioxide that exceed 1,000 ppm are a marker suggesting inadequate ventilation [56]. The United Kindom standards for schools say that carbon dioxide in all teaching and learning spaces, when measured at seated head height and averaged over the whole day should not exceed 1,500 ppm. The whole day refers to normal school hours (i.e. 9:00am to 3:30pm) and includes unoccupied periods such as lunch breaks [56]. In Hong Kong, the Environmental Protection Department established indoor air quality objectives for office buildings and public places in which a carbon dioxide level below 1,000 ppm is considered to be good [57]. European standards limit carbon dioxide to 3,500 ppm. Occupational Safety & Health Administration limits carbon dioxide concentration in the workplace to 5,000 ppm for prolonged periods, and 35,000 ppm for 15 minutes. These higher limits are concerned with avoiding loss of consciousness (fainting), and do not address impaired cognitive performance and energy, which begin to occur at lower concentrations of carbon dioxide [56].

An indoor Carbon dioxide concentration depends on the number of human occupancy and intake of fresh air. In lower air exchange rate CO_2 concentration will be higher.

Carbon dioxide concentrations in closed or confined rooms can increase to 1,000 ppm within 45 minutes of enclosure. For example, in a 3.5-by-4-metre (11 ft × 13 ft) size office, atmospheric carbon dioxide increased from 500 ppm to over 1,000 ppm within 45 minutes of ventilation cessation and closure of windows and doors [58].

h) Ozone

Ozone is produced by ultraviolet light coming from the suns contact with ozone layer of the earth. Ozone layer exists in the level of passenger jets flown. Larger jets have ozone filter to reduce the ozone concentration in the cabin. Reactions between ozone and onboard substances, including skin oils and cosmetics, can produce toxic chemicals as by-products. Ozone itself is harmful to the human health and damages lung tissues.

Sufficient amounts of ozone may be there in outdoor air and it mixes with the indoor air by ventilation. That ozone can react with common indoor pollutants as well as skin oils and other common indoor air chemicals. Some chemicals react very quickly with ozone to form toxic and dangerous chemicals.

2.4.2. Effect of indoor plants

Houseplants remove the CO_2 and release oxygen and water to the environment which leads to a reduction in the indoor air pollutants. It can also reduce the concentrations of volatile organic compounds in indoor air such as benzene, toluene, and xylene. Plants remove CO_2 and release oxygen and water, although the quantitative impact of house plants is small. The effect of house plants on VOC concentrations was investigated in one study, done in a static chamber, by NASA for possible use in space colonies [59]. The results showed that the removal of the dangerous chemicals was roughly equivalent to that provided by the ventilation that occurred in a very energy efficient dwelling with a very low ventilation rate, an air exchange rate of about 1/10 per hour [59]. Therefore, air leakage in most homes, and in non-residential buildings too, will generally remove the chemicals faster than the researchers reported for the plants tested by NASA. The most effective household plants reportedly included aloe vera, English ivy, and Boston fern for removing chemicals and biological compounds [59].

Plants also can reduce airborne microbes, molds, and increase the humidity of the surrounding environment. However, high humidity leads to increasing the level of mold that caused air pollution.

When CO_2 concentrations indoors become higher than outdoor level, it is an only indicator that ventilation is inadequate to remove metabolic products associated with human occupancy. Plants require CO_2 for their growth and release oxygen when they consume CO_2. A study has found that intake rates of ketones and aldehydes by the peace lily (*Spathiphyllum clevelandii*) and golden pothos (*Epipremnum aureum*) were 30−100 times more than the amounts dissolved in the leaf, suggesting that volatile organic carbons are metabolized in the leaf and/or translocated through the petiole." [60]

Fig 2-2: Spider plants (*Chlorophytum comosum*) and Aloe Vera absorb some airborne contaminants

3. CHAPTER THREE: RESEARCH METHODOLOGY

After reviewing the literature studies, a background was created and the study methodology was developed to achieve the research objectives.

3.1. Study Approach

3.1.1. Literature Review

After reviewing the various studies carried out for assessing thermal comfort and air quality in Sri Lanka and several other countries, the theoretical background and present situations were identified. From the literature available, relevant study parameters were selected for analyzing the thermal comfort and air quality in suburbs of Colombo, the capital city of Sri Lanka.

3.1.2. Experimental Study

Initially a pilot study was carried out to identify critical air quality parameters and causes that influence the air quality level in the selected area.

An experimental program was conducted to obtain several air quality parameters in rationally selected residential buildings based on the surrounding micro-climatic features. In addition, the type of building materials used and daily practices that can emanate air pollutants were also recorded.

The research methodology is summarized in Figure 3-1.

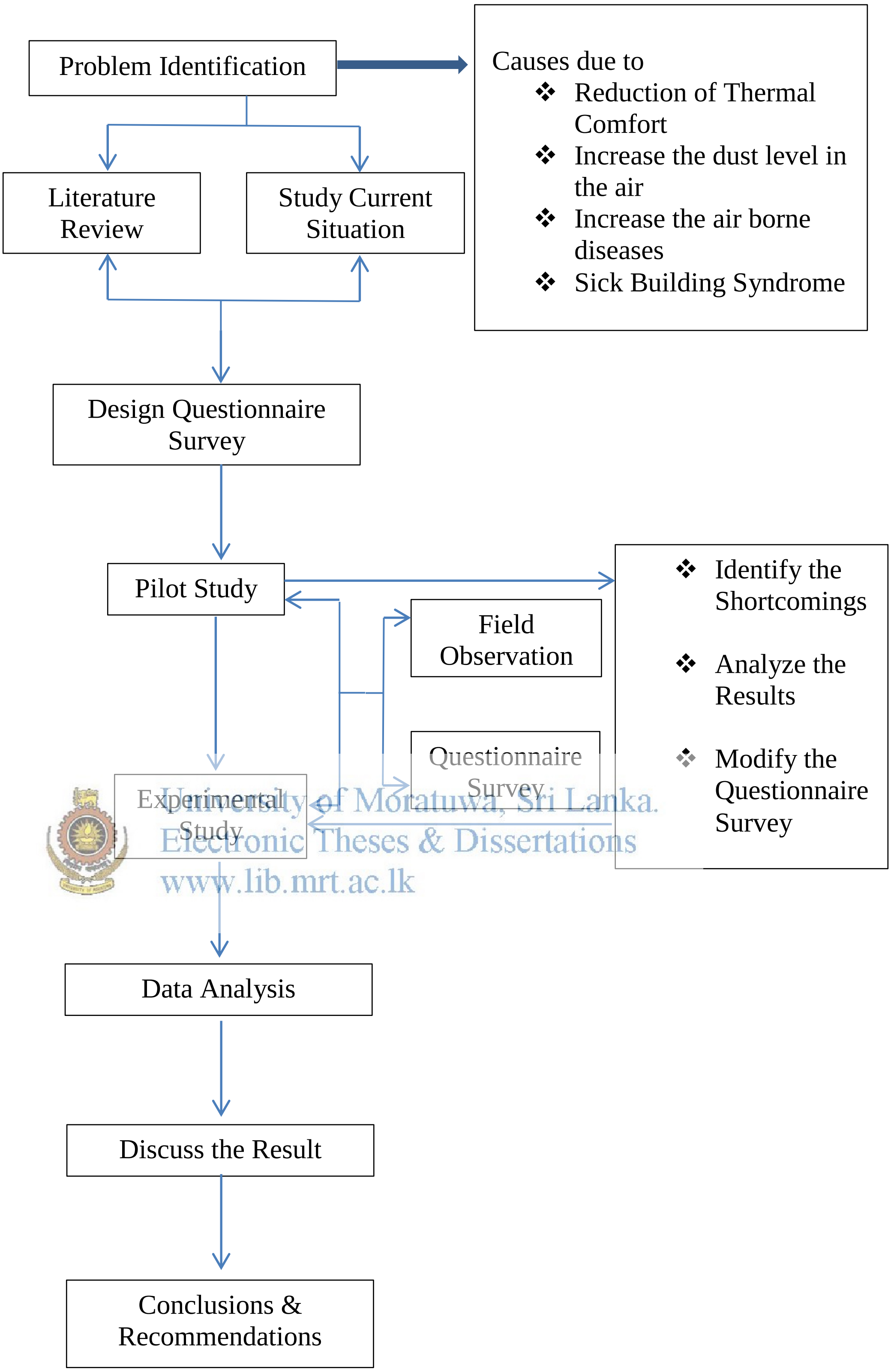


Figure 3-1: Flow Chart of Research Methodology

3.2. Study Location

This study was carried out in Kesbewa area which is situated in the southern periphery of Western province in Sri Lanka. Sri Lanka being a tropical country, this area is characterized by hot, humid climatic conditions having sunshine throughout the day. Mainly Colombo is affected by heavy rainfalls in most of the months in every year from the Southwest monsoon, two inter monsoons and thunderstorms appear in northwest monsoon. Because this area is situated in a lowland region, most of water bodies and green covers are naturally located within the area.

This area can be classified as a semi-urban area due to the presence of green patches in the form of paddy fields and groves in the developed area. The study area indicating the sample points is shown in Figure 3-2.

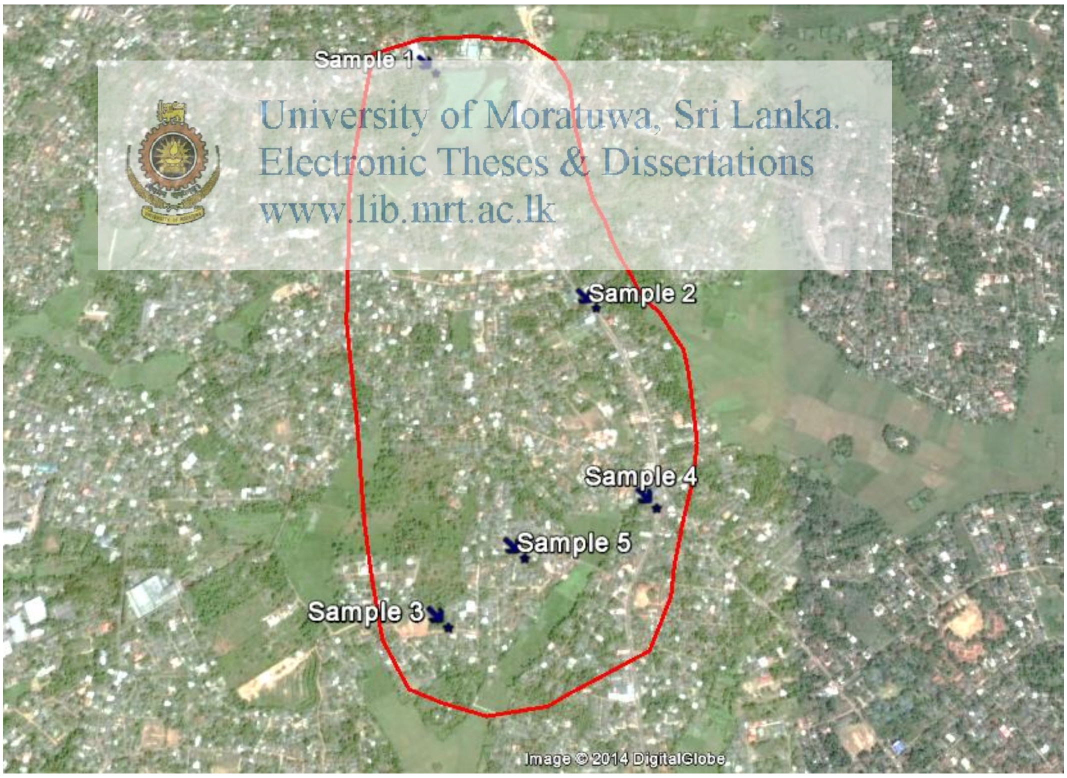


Figure 3-2: Site Map of the Study Area

Favorable and unfavorable microclimatic areas were considered for this study. Thus these samples were carefully selected considering the presence of vegetation and water bodies nearby and the distance to the main road. The considered microclimatic area was limited to the boundary of land area of the selected building.

The microclimatic features of the selected samples can be described in the following figures.

The First sample has the best microclimate surrounding the building. Kesbewa Lake is situated adjacent to the building. It has a thick surrounding vegetative cover. The building is situated 30m away from B 267, Colombo Horana Road.

Figure 3-3: Site Location of Sample 01

Figure 3-4: Site Location of Sample 02

The Second sample has directly opened to the B 216, Bandaragama Kesbewa Road. It is a small land having land area of 90 m^2 without any considerable vegetation surrounding the building. The Building has a poor ventilation system.

This is the furthest sample from the Main Roads. It has small amount of large trees and the balance part of the land is covered by grass.

Figure 3-5: Site Location of Sample 03

Figure 3-6: Site Location of Sample 04

The Forth sample is also adjacent to the B 216, Bandaragama Kesbewa Road. It has a good vegetative cover at the rear side of the Building and some bushes with a grass cover in front of the Building. A 2m high boundary wall has separated the Main Road and the Building.

This is situated 200m away from the B 216, Bandaragama Kesbewa Road. The Building has considerably less amount of vegetation surrounding the Building, but a better ventilation system is there.

Figure 3-7: Site Location of Sample 05

3.3. Method of Data Collection

3.3.1. Desktop Studies

In the initial study the research was focused on the detailed literature review on the level of permissible air quality. Indoor and Ambient Air Quality Guidelines used in different countries in comparison with their existing levels of air quality were studied. Then the study was focused to Sri Lankan current situation and National Ambient Air Quality Standard published in Sri Lanka was reviewed.

The microclimatic analysis methods were studied. In addition analyzing methods of favourable comfort levels were reviewed.

3.3.2. Field Observations

The experiment was carried out in the months of August and September in the year 2014 in selected residential buildings in Kesbewa suburb of Colombo. In order to assess the level of air quality in the selected residential buildings, indoor concentrations of Carbon Dioxide (CO_2), Nitrogen Dioxide (NO_2), Carbon Monoxide (CO) and Volatile Organic Compound (VOC) were measured in two minutes interval and Particulate Matter ($PM_{2.5}$) was measured in one minute interval throughout a day from 9.00 AM to 4.00 PM in each sample building. The temperature, relative humidity (RH) and wind speed were also obtained to perceive the thermal comfort inside. The data collection points were located in the middle of the living room in all the sites.

Using the Air Quality Monitor, IQM 60 which is integrated with photo-ionization detector (PID) and non-dispersive infra-red (NDIR) sensors and Haz-Dust EPAM 5000 a real-time particulate monitor designed for ambient environmental and indoor air quality applications, the air quality levels and concentration of particulate matters ($PM_{2.5}$) were measured in the selected buildings.

Figure 3-8: Setup of Air Quality Monitor & Haz-Dust EPAM 5000 real-time particulate Monitor

Wet & Dry Bulb Hygrometer and Portable Carbon Dioxide Monitor were placed outside of the building to measure the outdoor Temperature and Carbon Dioxide levels.

Figure 3-9: Setup of Wet & Dry Bulb Hygrometer & Portable Carbon Dioxide Monitor

In addition to the indoor and outdoor air quality parameters wind speeds and light levels were measured in 30 minutes intervals using Low Speed Air Meter and Lux Meter.

Figure 3-10: Low Speed Air Meter and Lux Meter

Possible indoor air pollution sources were investigated to justify the deviations indoor pollutant levels in air with respect to outdoor micro-climate, if there is any. Types of the building materials, usage of body/hair spray, air fresheners, insecticide and tobacco smoking were included in the investigation criteria. As well, any symptoms caused due to air pollution were examined through the occupants.

3.3.3. Questionnaire Survey

Questionnaire survey was conducted in parallel with the field observations. The data was collected from 22 persons living in the selected 5 houses. The contents of the questionnaire survey include details of the site and building, building characteristics, details of the kitchen with their chimney location, normal daily routings of the occupants and health related issues of the occupants. The symptoms elicited from the questionnaire include nausea, dizziness, sore throat, runny nose, sore eyes, lethargy and headache.

3.4. Method of Data Analysis

The air quality data obtained from the field measurements were initially checked against the threshold values of each pollutant to evaluate the level of air quality in residential buildings. Then they were compared with the existing micro-climatic conditions, specially the vegetation, to study the impact of micro-climate on indoor environmental quality.

The dimensions of the building and the amount of vegetation were obtained to quantify the micro-climatic features in the vicinity of the building. The extent of micro-climate under consideration was limited to the extent of the land in which the building is situated. These micro-climatic features of selected samples were divided into three main categories. These are;

1. Vegetative cover – The area of the land covered by vegetation
2. Hardscape – The area of the land covered by the building (plot coverage), concrete pavement and other man-made structures
3. Soil cover – The area of land left without vegetation or hardscape

Outdoor temperature, relative humidity and wind speeds were used to rationalize the deviations that could have occurred in observation due to the variations of daily climatic conditions.

Then the temperature deviation from thermal neutrality was checked to analyze the thermal comfortable of occupants in the selected area. A psychometric chart including the comfort zone was used to compare the thermal conditions of the chosen buildings. All buildings have only natural ventilation system. So that a psychometric chart with the extended comfort zone that consider the natural ventilations is used for analysis.

Finally, a statistical analysis was carried out based on the data received from Questionnaire survey.

4. CHAPTER FOUR: DATA ANALYSIS

4.1. Analyze the micro-climatic features in the selected area

This area consist of different micro-climatic features, some of them make positive impacts as vegetative cover or water bodies and some of them make negative impacts as artificial structures or distance from main roads. The details collected from each sample are described as in the Table 4-1.

Table 4-1: Details of sample sites

Sample Site	**1**	**2**	**3**	**4**	**5**
Site Details					
Area of the land (m^2)	3125	90	500	975	250
Floor Area of the building (m^2)	684	47	116	247	65
Plot coverage (%)	22%	52%	23%	25%	26%
Area of paving slab/ concrete roads (m^2)	38.75	17.25	14.30	54.60	29.10
Hardscape (%)	23%	71%	26%	31%	38%
Micro-climatic features					
Soft scape (%)	77%	29%	74%	69%	62%
Vegetative cover (%)	68%	2%	62%	59%	41%
Soil cover (%)	9%	27%	12%	10%	21%
Data collection points					
Area of the living room (m^2)	68.70	14.85	24.40	52.80	41.25
Void to floor ratio	19%	30%	37%	15%	24%
General Details					
Adjacent main road	B 267	B 216	B 216	B 216	B 216
Distance from the site (m)	30	2	500	5	200
Daily traffic (No. of vehicles)	6500 – 7000	6500 – 7000	6500 – 7000	6500 – 7000	6500 – 7000

The significant effect of micro-climate on air quality parameters was observed in this study. The impact on each parameter is described separately in the next chapter.

The effect of vegetation on micro-climate should be taken in to account in terms of horizontal and vertical distribution. Hence the amount of vegetative cover was analyzed considering the height of trees as well.

Table 4-2 describes below the vertical distribution pattern of the trees with respect to the horizontal distribution.

Table 4-2: Vertical Distribution of Vegetation

Sample Site	**1**	**2**	**3**	**4**	**5**
Area of trees above 15m (m^2)	1062	0	0	350	0
Vegetative Coverage (%)	34%	0%	0%	36%	0%
Area of trees 15m-10m (m^2)	446	0	0	162	0
Vegetative Coverage (%)	14%	0%	0%	17%	0%
Area of trees 10m-5m (m^2)	314	0	17	0	4
Vegetative Coverage (%)	10%	0%	3%	0%	2%
Area of bushes below 5m (m^2)	97	2	3	14	29
Vegetative Coverage (%)	3%	2%	1%	1%	11%
Area of grass cover (m^2)	202	0	288	54	70
Vegetative Coverage (%)	7%	0%	58%	5%	28%
Total area of vegetation (m^2)	2121	2	308	580	103
Total Vegetative Coverage (%)	68%	2%	62%	59%	41%

Chart 4-1 illustrates the comparative distribution of micro-climatic features in the sample sites.

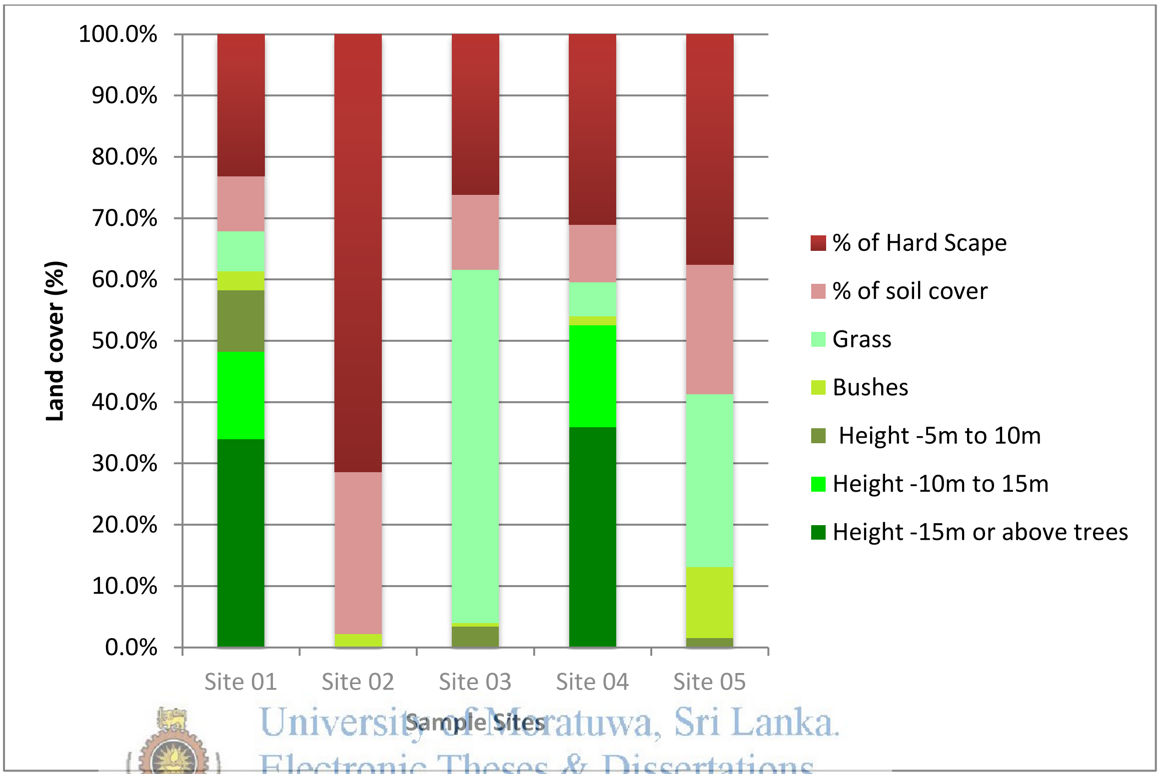


Chart 4-1: Percentage of micro-climatic features in the Sites

According to the chart 4-1 and Table 4-2, Site 1 has the most favorable microclimate towards the indoor air quality and thermal comfort with 68% of vegetative cover. With the presence of Kesbewa Lake nearby, this site can be identified as the best case scenario. Site 2 can be identified as the worst case scenario with 2% of vegetative cover having only three plants of 1m height and the adjacent Bandaragama – Kesbewa main road which is having asphalt paved surface.

Figure 4-1 shows the level of vegetation in the site 1 (Best case scenario) and the site 2 (Worst case scenario).

(a) (b)

Figure 4-1: Level of vegetation in the sites; (a) - site 1 (Best case) & (b) - site 2 (Worst case)

Even though the site 4 is also having reasonably the same percentage of vegetation compared to site 01, the vegetation in the site was clogged in the rear side of the building where the vegetation in the site 01 was distributed around the building providing a shade in every direction. Hence the effect of the vegetation on the indoor environment has reduced in the site 4 compared to site 1.

(a) (b)

Figure 4-2: Level of vegetation in the site 4; (a) – front view & (b) – rear view

When we consider the sites 3 and site 5, both are having less vegetative cover with respect to the tree heights. But both have grass cover on the land. That means total effect due to their vegetation level is comparatively low. As well the sites are situated a considerable distance away from the main roads. It has caused to improve the surrounding environment because environmental disturbances due to commercial activities and vehicle movements in the main roads rarely influence the surrounding climate of sites.

4.2. Analyze the Indoor Air Quality

Recorded indoor air pollutants have been compared with the maximum permissible values published in World Health Organization (WHO) Guideline and United State Environmental Protection Agency (USEPA) Guideline to check whether it has detoriated the air quality by exceeding the threshold values. They have published regulatory values only for selected air pollutants. There is also no regulation published in Sri Lanka to regulate the indoor air quality.

Table 4-3: Maximum permissible level of the indoor air pollutants

Air quality parameter/ Exposure time		WHO Guidelines	US EPA Guideline
CO_2			5000 ppm
NO_2	1 hr	200 µg/m^3 / 0.106 ppm	100 µg/m^3 / 0.053 ppm
	Annual	40 µg/m^3 / 0.021 ppm	
$PM_{2.5}$			15 µg/m^3
CO	15 min	100 mg/m^3 / 87 ppm	
	1 hr	35 mg/m^3 / 31 ppm	
	8 hr	10 mg/m^3 / 9 ppm	9 ppm
	24 hr	7 mg/m^3 / 6 ppm	

Normally Guidelines give the threshold level of CO_2 concentration as 5000 ppm which is the value directly related to health risk. However according to the US EPA Guideline, CO_2 concentration is an indicator of human ordor (odorous bio-effluents) and acceptability level of the ordor is 1000 ppm.

The stringent threshold values from the two Guidelines are compared with the recorded values to check the air quality levels. Air pollutants were recorded in terms of the concentrations of CO_2, NO_2, CO, $PM_{2.5}$ and VOC. But there were no detectable levels of VOCs in all the sites. Therefore comparison was focused to other air quality contaminants.

Table 4-4: Recorded range of the air pollutants inside the building

Air quality parameter	Threshold value	Sample site				
		1	2	3	4	5
CO_2(ppm)	1000	413 - 498	470 - 600	447 - 542	420 - 554	399 - 541
NO_2(ppm)	0.053	0.023 – 0.039	0.024 – 0.038	0.021 – 0.031	0.017 – 0.025	0.017 – 0.027
$PM_{2.5}$(mg/m^3)	0.015	0.002 – 0.065	0.001 – 0.097	0.001 – 0.025	0.002 – 0.095	0.001 – 0.040
CO (ppm)	9	0.00 – 0.06	0.00 – 1.93	0.00 – 0.02	0.00	0.00

The air quality in all the residential buildings is in the acceptable range except the $PM_{2.5}$ concentration as shown in Table 4-4. The concentration of particular matter exceeds the threshold value at some peak points through out the time period. More explanation for the reasons behind the high levels of $PM_{2.5}$ concentration have been given in Section 5.1.3. The proposed controlling method for $PM_{2.5}$ is described in the Section 5.2.1.

Even though there were two occupants inside the room at the time of investigation, maximum CO_2 concentration recorded was 600 ppm. It should be noted that all these residential buildings are naturally ventilated and the favorable level of CO_2 concentration can be attributed to the natural ventilation provided.

It can be observed that the considerable CO concentration recorded in the site 2 and data shows that there was a detectable level of CO throughout the day. Even though the recorded CO concentrations are well below the threshold value, it is advisable to maintain zero CO condition. The continuous exposure to CO gas may create some long term health issue.

4.3. Analyze the thermal comfort

Initially the analysis is directed to the occupants' statements regarding the comfort levels. Only persons in the site 01 have satisfied with their surrounding environment. Thermal sensation responses from the occupants in other sites are beyond the neutral level, warm or slightly warm.

Chart 4-2 describes the comparison of thermal sensation of the occupants, based on their statements during the Questionnaire Survey.

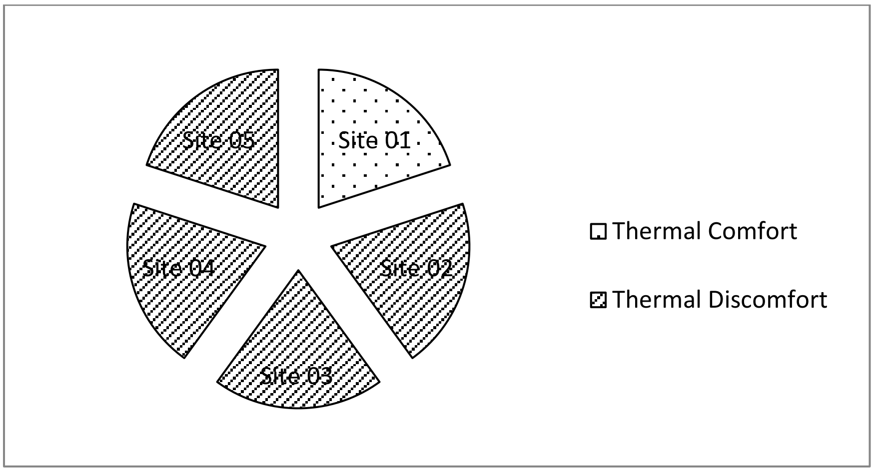


Chart 4-2: Comparison of thermal sensation of the occupants

Then average values of recorded indoor temperature and relative humidity have been used to check the thermal comfort level inside the buildings.

Table 4-5: Daily Average Indoor and Outdoor Temperature and Relative Humidity

	Sample site				
	1	2	3	4	5
Indoor Temperature (^{0}C)	28.9	29.3	29.6	32.3	32.3
Indoor RH (%)	77.8	78.3	77.6	68.6	66.6
Outdoor Temperature (^{0}C)	28.5	28.5	29.3	34.8	33.0
Outdoor RH (%)	83.9	86.9	80.7	64.7	64.1

Daily average temperature and relative humidity values have been plotted on the psychometric chart to compare the comfort levels as in the figure 4-3.

According to the figure 4-3, except site 01, the indoor comfort level of other all sites have located at the boundary or out of the comfort zone. The indoor comfort level of site 01 which is having the best vegetative cover has only located within the boundary. It also comparatively shows that the condition of indoor and outdoor in site 01 is almost same. Other sites have comparatively higher difference in indoor and outdoor comfort levels. It has been interpreted as only site 01 has the comfortable environment and occupants in other sites feel thermal discomfort.

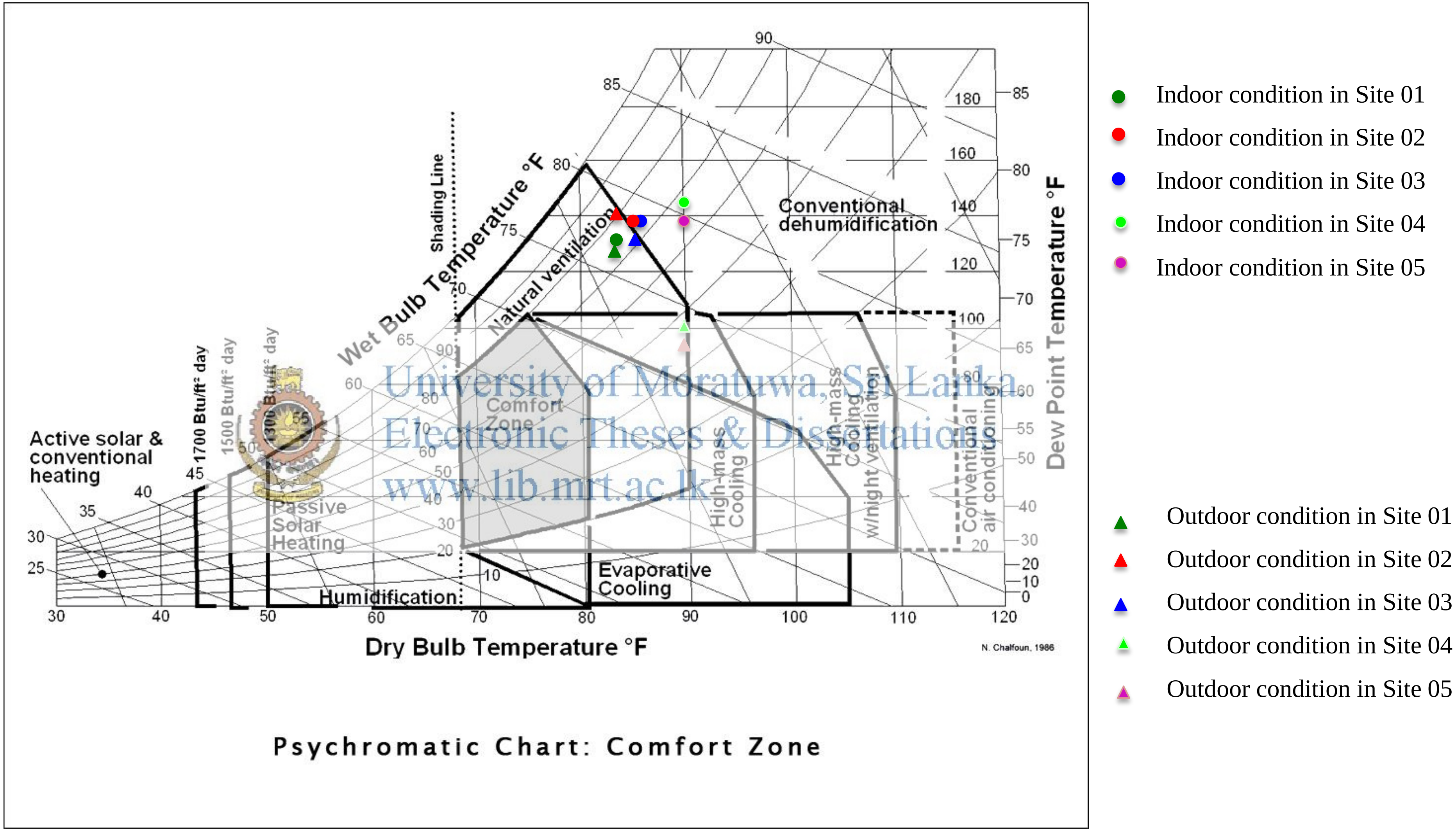


Figure 4-3: Comfort Levels of the selected buildings plotted on the psychometric chart

4.4. Questionnaire survey

The main aspects of conducting a Questionnaire survey are to find the causes for air pollution and thermal discomfort exist in the indoor environment and investigate the health and wellbeing of the occupants.

4.4.1. Indoor Pollution Sources & Thermal Discomfort

The kitchen of a building is a leading place to make different type of air pollutant contaminants. On the other hand the Fireplace in a residential building is significant source of air pollution. It makes CO_2, CO, NO, NO_2, etc gases which caused to adverse health impacts. Additionally the undesirable gases, a hearth has caused to disperse fine particulate matters to the air. When comparing the sources of fire in the kitchen, gas cooker adds comparatively more gasses into the surrounding air.

The chart 4-3 shows the average selection of fireplaces in the selected buildings.

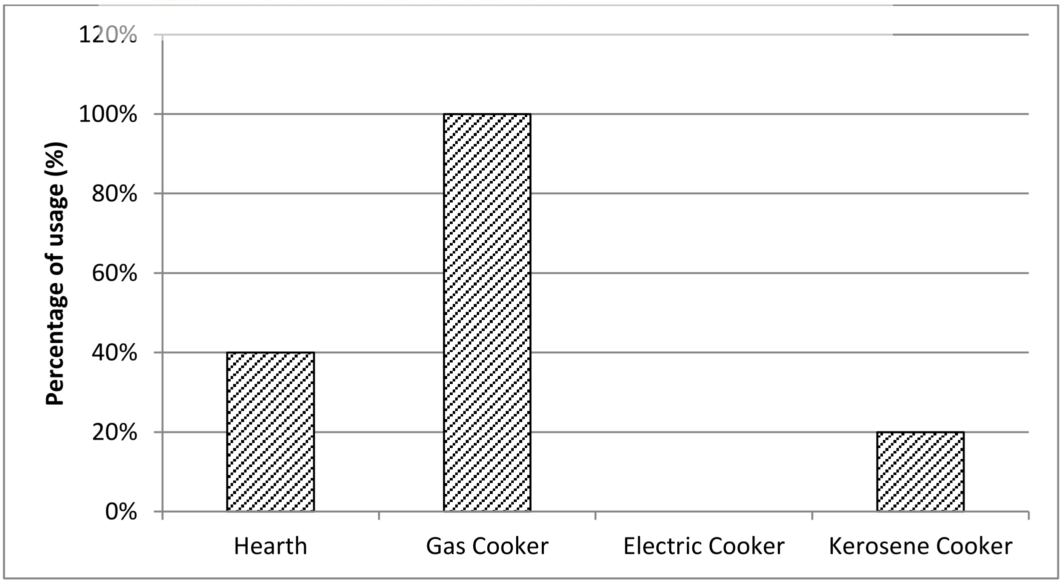


Chart 4-3: Percentage of fireplaces

According to the chart, almost all of houses in this area use gas cookers. Gas cooker users also have wooden hearth (site 01 and site 04) or kerosene cooker (site 03) as an optional one. However the major requirement has been fulfilled with a gas cooker. As the gas cooker is a significant source of indoor air pollution, the buildings have a great influence to increase indoor pollutants like CO, CO_2, NO_2, etc.

A chimney placed at the fireplace has great influence to dilute the indoor air pollutants produced from the fireplace. The availability of chimney at the kitchen in the selected buildings is shown in Chart 4-4.

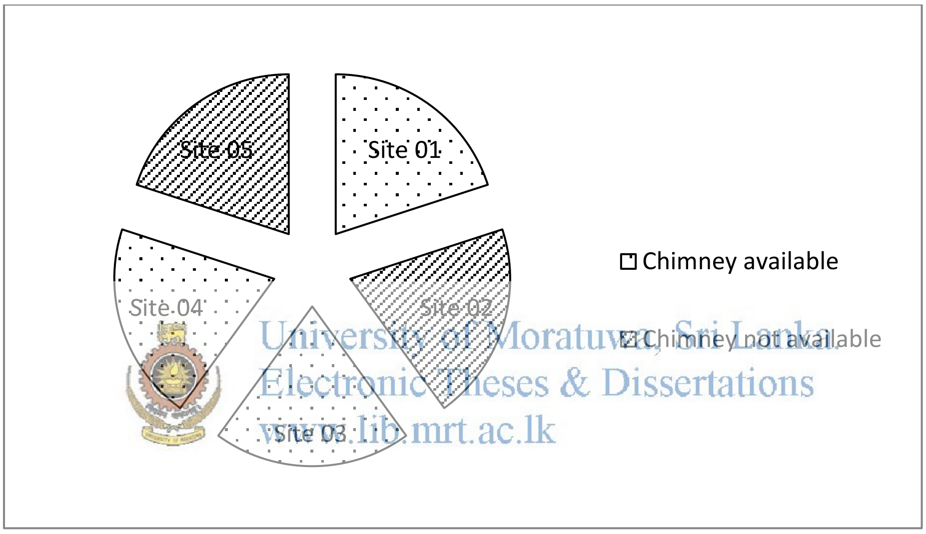


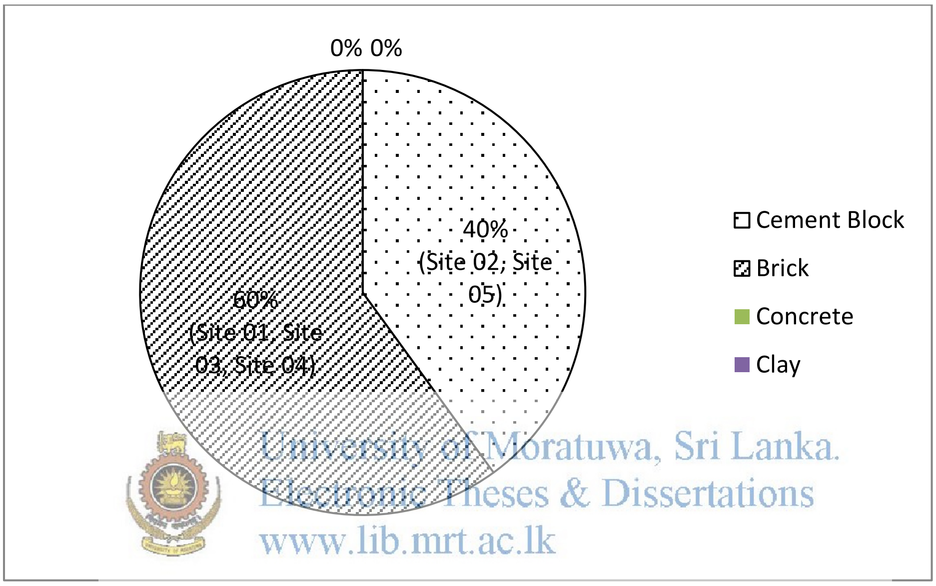
Chart 4-4: Availability of Chimney

According to the chart 4-4, there are two fireplaces in site 02 and site 05 that do not have a chimney. They have used only a gas cooker for cooking. Gas cooker emit more undesirable gases to the indoor air and it collects inside the house if there is not a chimney and good ventilation system. it cause to increase the indoor air pollutants greatly.

As well Building construction materials have a considerable contribution to increase the indoor air pollution and thermal discomfort. It was analyzed in terms of walling materials, roofing materials and ceiling materials.

The walling materials directly affect to the thermal comfort. Walling materials, considered in this study as cement block, brick, concrete and clay have differently responded to the solar radiation. Past studied shows that Brick and clay walls significantly reduce the thermal discomfort inside the building.

Chart 4-5 illustrates bellow, the walling materials used for the buildings in the selected area.



Char 4-5: Walling materials

According to the chart people used only cement block or brick as a wall material. 60% of the buildings as site 01, site 03 and site 04 have brick walls in their houses and it helps to maintain the thermal comfort inside the building.

Roofing material has caused to the indoor air pollution together with thermal discomfort. In this study area people use clay tile, asbestos sheets and concrete slab for their roofing.

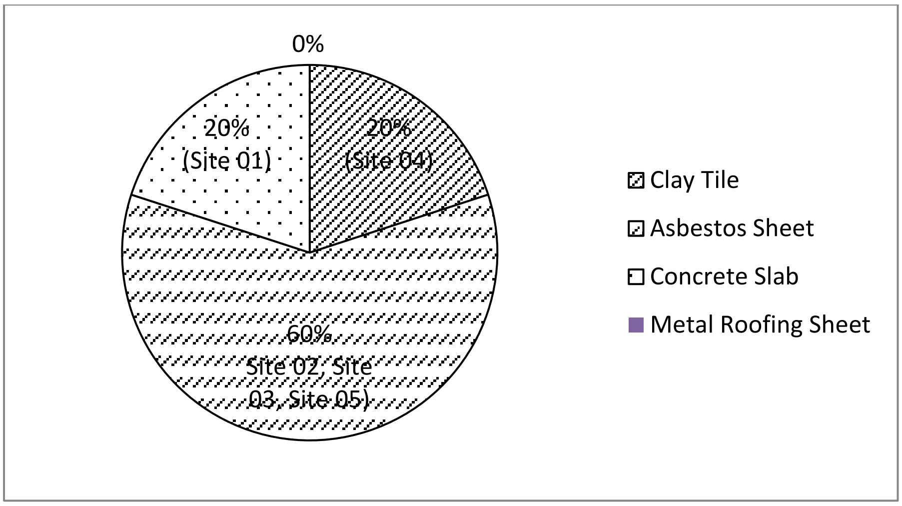


Chart 4-6: Roofing material

Asbestos sheet and concrete slabs have a capacity to absorb more solar radiation and it slowly emit. It cause to heat inside air of the building. According to the chart 4-6, only site 04 has a roof with clay tiles.

The ceiling material has also influenced the thermal comfort. In the selected study area 40% of the houses (site 01 and site 03) have not a ceiling and they are directly exposed to the effects of roofing material.

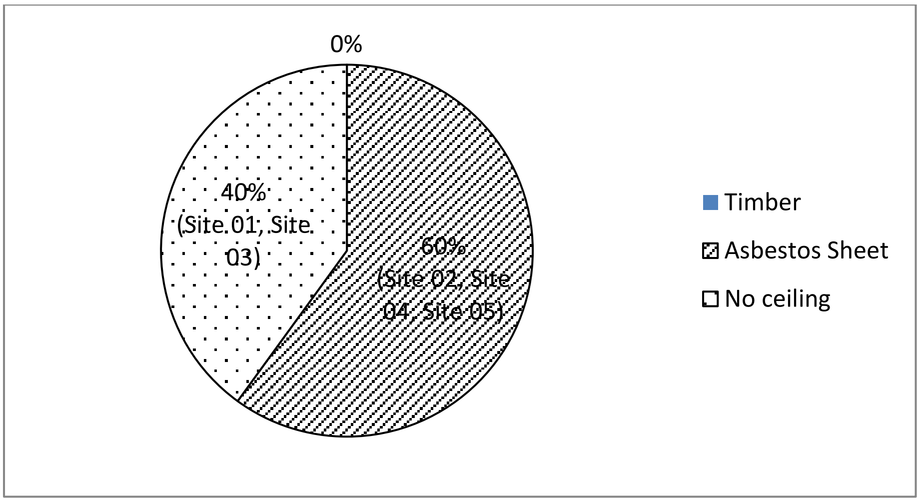


Chart 4-7: Ceiling material

According to the chart, out of the people who have a ceiling in their house, 100% of occupants use asbestos sheet for their ceiling materials. It is a main reason for thermal discomfort.

The daily routing activities also cause to the indoor pollution. The following chart shows some activities done by the occupants. By these activities some hazardous materials can emit to the environment.

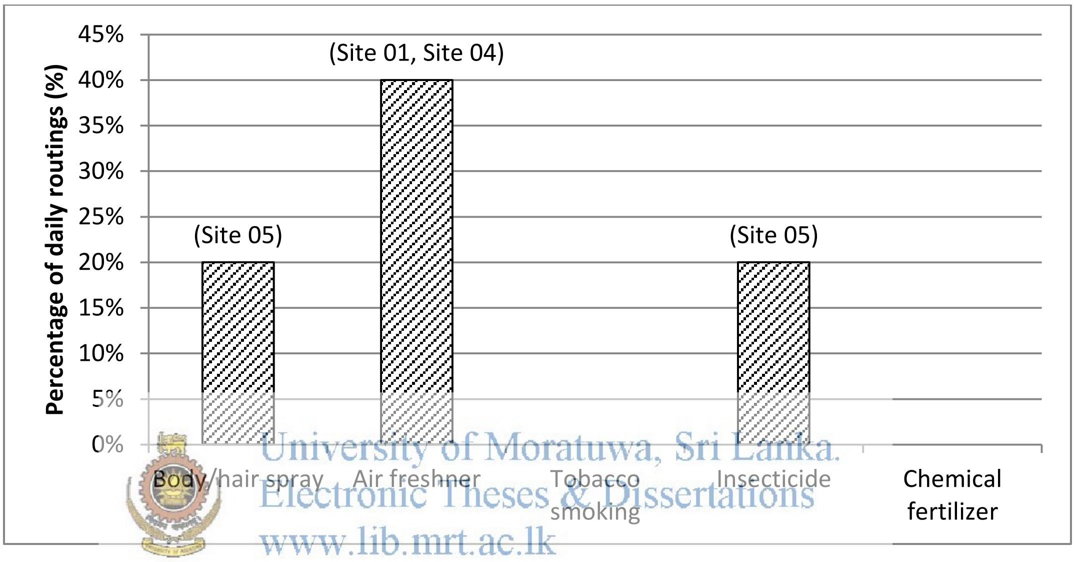


Chart 4-8: Source of hazardous contaminants emit to the air

According to the chart 4-8, usage of air freshners is considerably higher in the selected area. Usage of air freshners, body spray, hair spray or insecticides makes the indoor air more toxic. They add some pollutant contaminants to the air as formaldehyde, petroleum distillates, aerosol propellants, p-dichlorobenzene, etc. Therefore increasing the percentage of usage of these hazardous materials will cause to increase indoor pollution and the health issues in future.

4.4.2. Health Effects

The occupants have some of the discomfort symptoms related to the indoor air environment. The following chart shows the discomfort symptoms of the occupants.

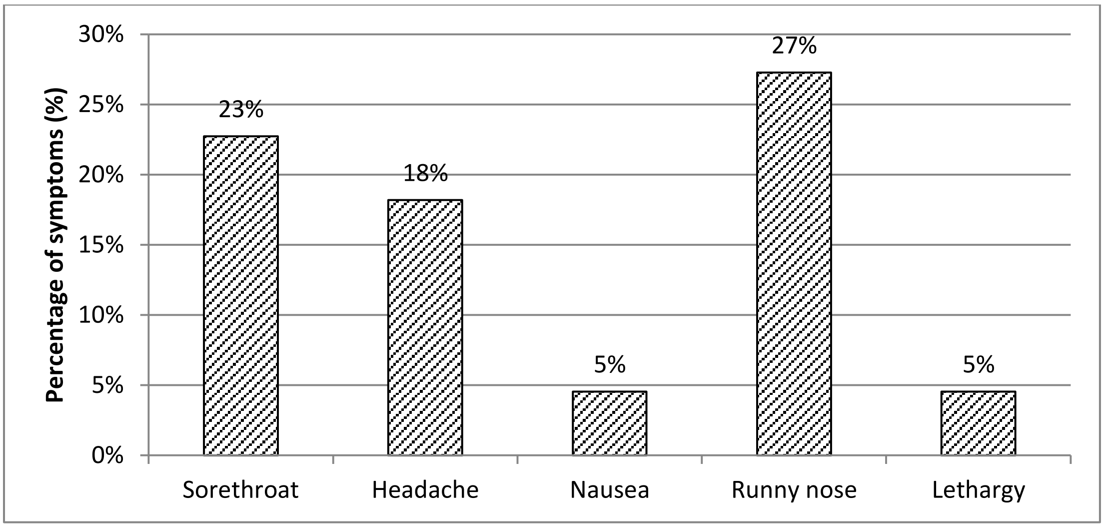


Chart 4-9: Percentage variation of discomfort symptoms

According to the chart occupants reported to have runny nose and sore throat comparatively higher percentage. It has mainly caused due to the considerable concentration of particulate matter in the air. Increasing the percentage of symptoms shows the level of poor air quality, and it tends to increase the sick building syndrome. However the percentage of runny nose and sore throat also less than 30%.

5. CHAPTER FIVE: RESULTS AND DISCUSSION

5.1. Effect of micro-climatic features on air quality parameters

5.1.1. CO_2 Concentration

The variation of indoor CO_2 concentration is shown in Chart 5-1. The chart illustrates that indoor CO_2 concentrations becomes maximum in site 2 that has less vegetation surrounding the building. However it is also well below the threshold level of 1000 ppm for the acceptability of odorous bio-effluents.

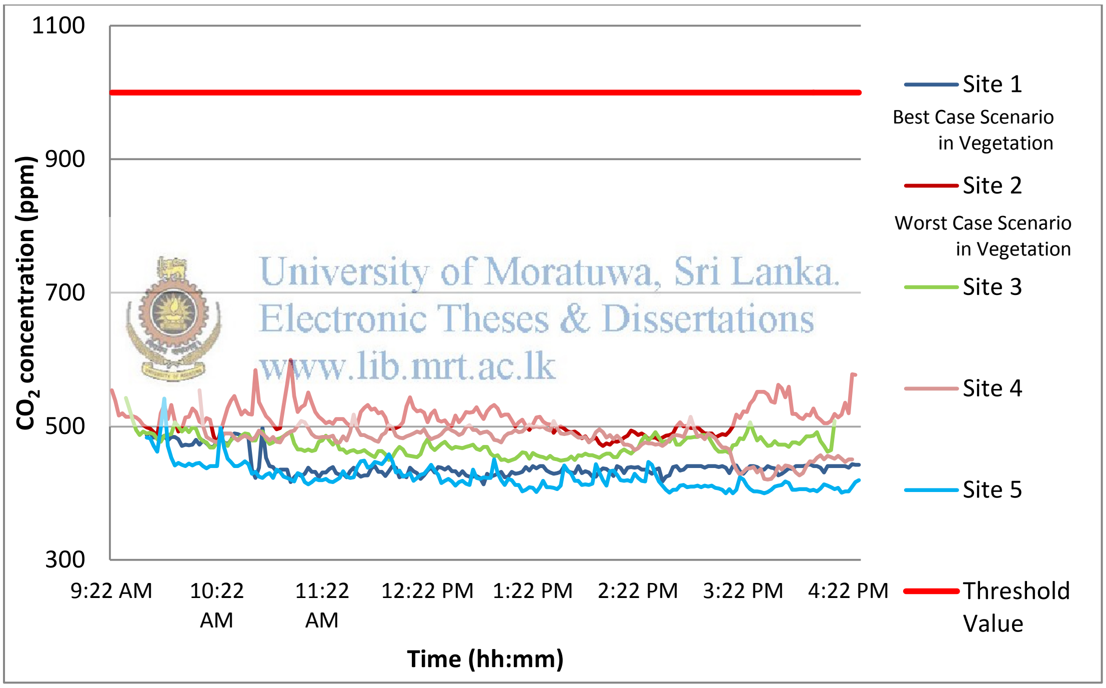


Chart 5-1: Variation of Indoor CO_2 level with time

When consider the correlation coefficients with respect to indoor CO_2 level and vegetation it shows the correlation coefficient of -0.57. This statistical phenomenon describes the nature of this situation that has the negative relationship of indoor CO_2 level with vegetation.

However the indoor CO_2 concentration mainly depends on the outdoor concentration in naturally ventilated buildings. All these selected building sites are naturally ventilated.

So that further, Chart 5-2 shows the Indoor CO_2 concentration / Outdoor CO_2 concentration ratio throughout the daytime.

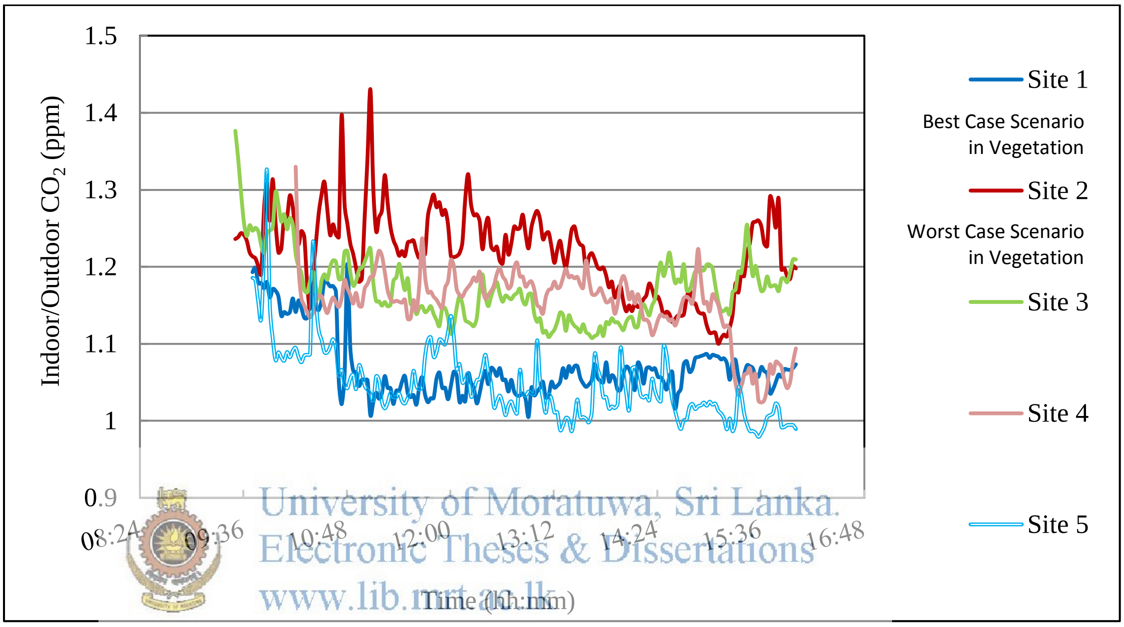


Chart 5-2: Variation of Indoor-Outdoor CO_2 with time

When study the relationship between Indoor/Outdoor CO_2 level with vegetation, it shows the relationship with -0.52 correlation coefficient. It also illustrates the relationship with vegetation although it is not stronger than the relationship between Indoor CO_2 level and vegetation.

According to the Chart 5-2, site 1 and site 5 have the lowest Indoor to Outdoor CO_2 concentration. Site 1 has the maximum outdoor vegetative cover and it has helped to reduce the CO_2 concentration outdoors. The moderate indoor and outdoor wind speeds of 0.15 ms^{-1} and 0.27 ms^{-1} respectively has resulted in creating the same CO_2 level inside compared to that outdoors. Although site 05 has lesser vegetative cover, it has a comparatively higher indoor and outdoor wind speed amounting to 0.14 ms^{-1} and 0.49 ms^{-1} respectively. Thus the indoor CO_2 concentrations may have diluted as a result of proper air circulation inside. Site 2 has the highest indoor CO_2 level because of its poor ventilation and very low wind speeds of 0.04 ms^{-1} inside and 0.19 ms^{-1} outside. The absence of vegetation around the building has aggravated the issue.

When consider the correlation coefficient between Indoor to Outdoor CO_2 concentration and Indoor Wind Speed, it gives the correlation coefficient of -0.82, strong relationship. It shows Indoor to Outdoor CO_2 concentration strongly related with the air circulation inside the building.

5.1.2. NO_2 Concentration

Chart 5-3 shows the indoor NO_2 variation in selected sites. Site 1 and site 2 have shown a similar variation having lower NO_2 concentration in the morning with the increase of concentration towards day time. Moreover, the highest NO_2 concentration was recorded in the site 1 and site 2 compared to the other sites. Hence a strong relationship between the NO_2 concentration and vegetation could not be established since site 1 and site 2 have the maximum and minimum vegetative cover respectively. When consider the correlation between vegetation and NO_2 concentration, it gives only -0.29 correlation coefficient. It shows there is no relationship with vegetation and NO_2 concentration.

However this observation can be linked with the distance to the NO_2 generated sources from the sites. Site 1 is situated nearly 30m away from the main road and there is a fuel station at the distance of about 50m from the site 1. Also their vehicles are in open garage adjacent to the main building. Site 2 located only 2m away from the main road and the entrance of the building is directly opened to the main road. It can be observed that these features have attributed to the higher NO_2 concentration inside the buildings located in site 1 and site 2 than in the other sites. So correlation coefficient was found to see the relationship. It is the value of -0.18. That means there is no relationship with NO_2 concentration and distance to NO_2 sources.

However, it should be noted that all the sites have recorded lesser NO_2 concentrations than the maximum permissible level of 0.053 ppm.

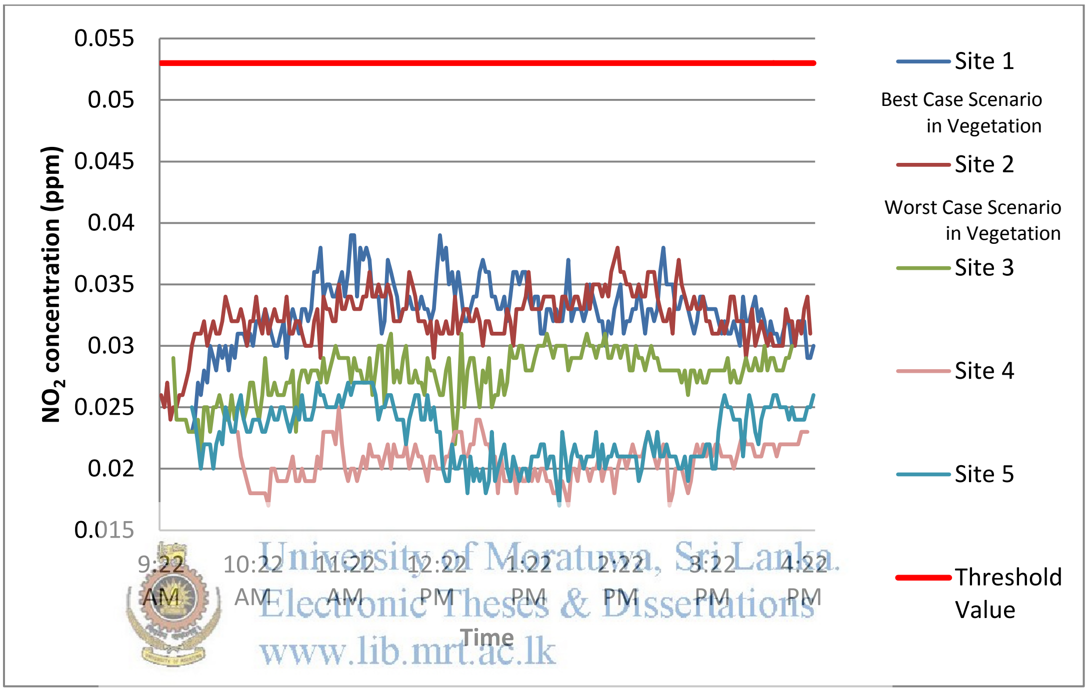


Chart 5-3: Variation of NO_2 concentration with time

5.1.3. Particular matter ($PM_{2.5}$) Concentration

The daily variation of $PM_{2.5}$ concentration is shown in the Chart 5-4. It can be observed that the site 2 has the highest average $PM_{2.5}$ concentration of 0.014 mg/m^3 with the highest peak value and values exceeding the threshold limit in a greater frequency. The site 3 has the lowest average $PM_{2.5}$ concentration of 0.004 mg/m^3 peaking only once beyond the threshold level. It should be noted that site 2 is closest to the main road being only 2m away and site 3 is furthest to the main road.

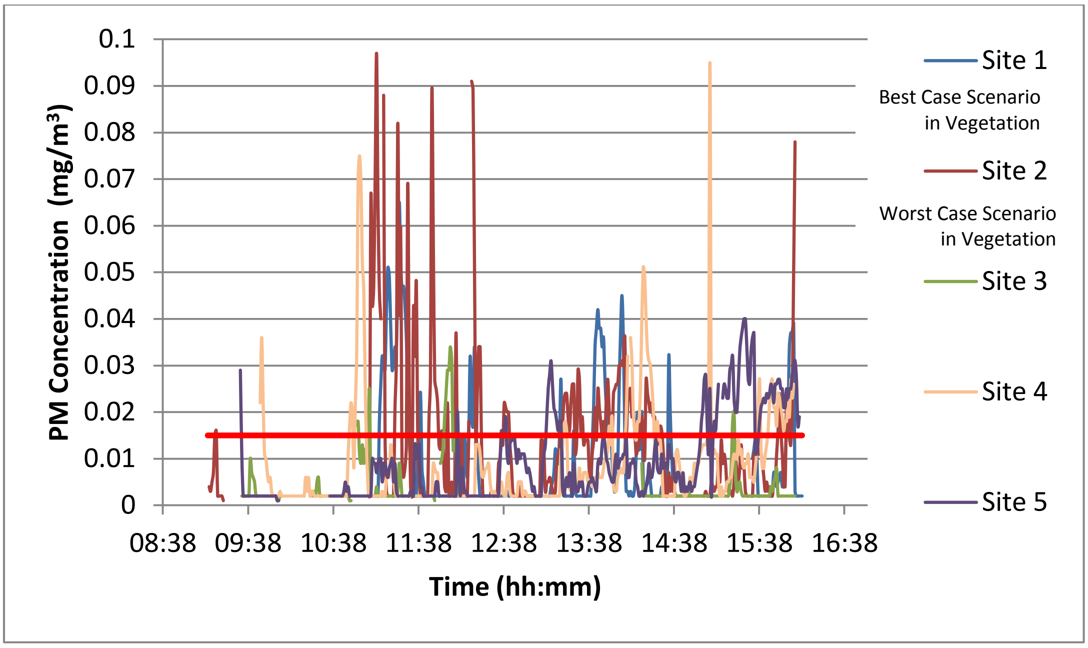


Chart 5-4: Variation of $PM_{2.5}$ concentration with time

The correlation coefficients of indoor particular matter concentration are -0.73 for vegetation and -0.83 for distance from main roads. It shows strong negative relationship between indoor particular matter concentration and the distance from main road while there is another negative relationship between indoor particular matter concentration and vegetation.

Chart 5-5 shows the daily averages of $PM_{2.5}$ concentration plotted against the distance to the main road. A declining trend of $PM_{2.5}$ concentration with the increase of the distance cover can be clearly observed with the coefficient of determination (R^2) value of 72.8%.

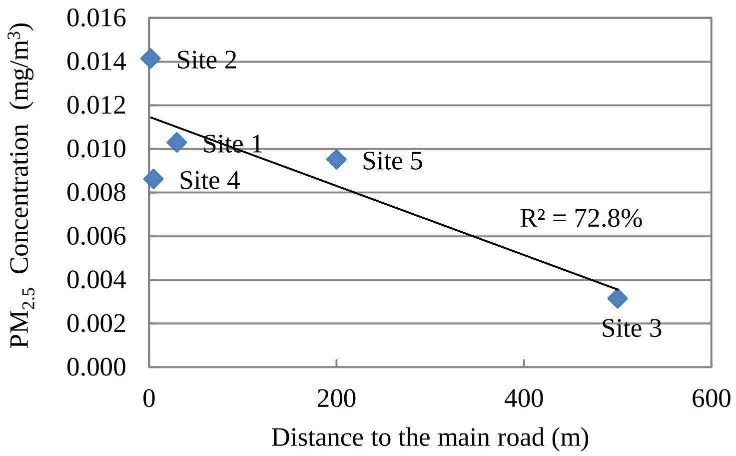


Chart 5-5: $PM_{2.5}$ concentration variation with the distance to the main road

As well Chart 5-6 shows the daily averages of $PM_{2.5}$ concentration plotted against the % vegetation cover. It also shows a declining trend of $PM_{2.5}$ concentration with the increase of the % vegetation cover, with the coefficient of determination (R^2) value of 53.5%.

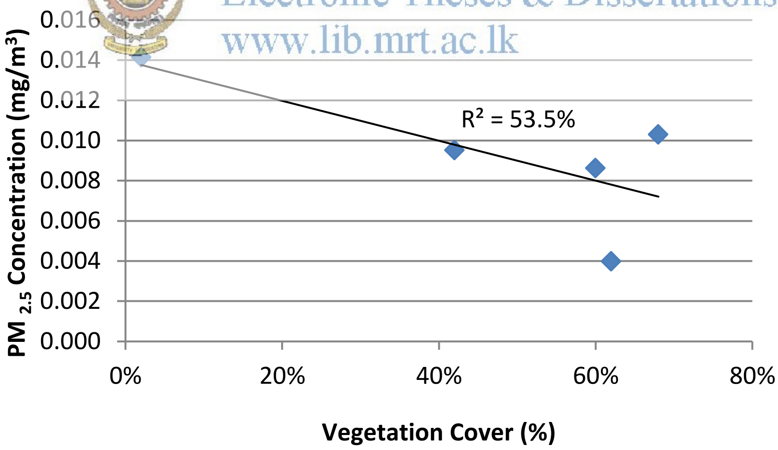


Chart 5-6: $PM_{2.5}$ concentration variation with the % vegetation cover

5.1.4. CO Concentration

According to the chart 5-7, it is observed that CO contaminant exists in air only in site 2 throughout the day. But it is well below the threshold level for a health risk. However long term exposure to the CO may cause health problem due to slightly increasing carbooxyhaemoglobin (COHb) concentration in blood day by day.

It is noted that there are many reasons to considerable level of CO concentration only in site 2. The site is the closet to the main road having the distance from site of 2m and 30% of the openings were to the wall facing the road. So the vehicular emission can directly enter to the building. The kitchen of this house has also no proper ventilation system and all gases generated in cooking disperse inside the house. Thus the vehicular emissions and gasses born by cooking have caused detectable levels of CO concentrations.

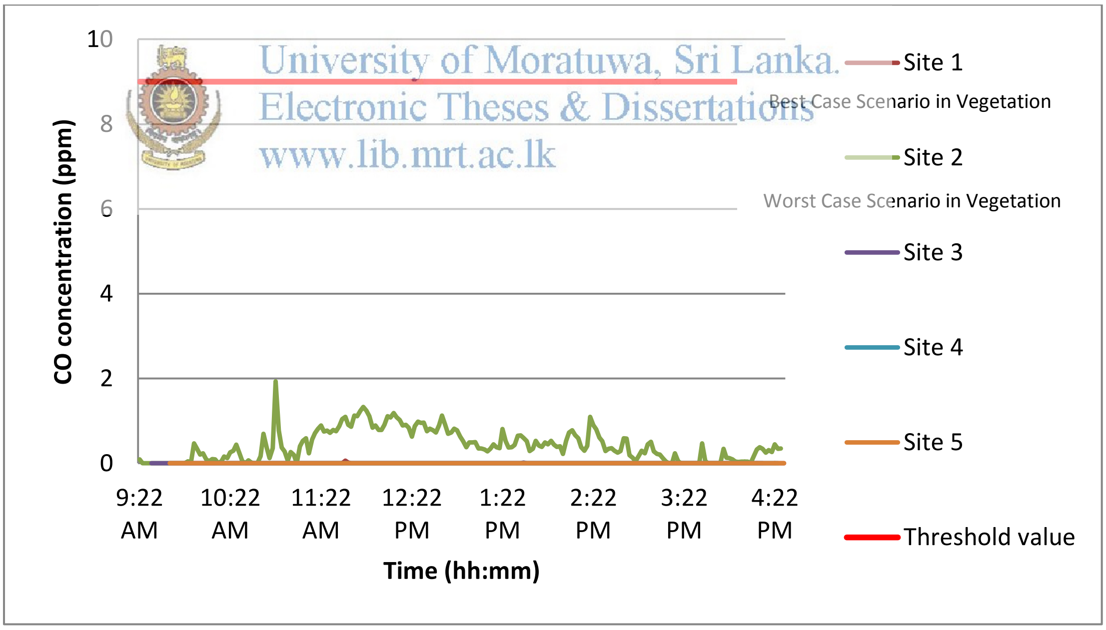


Chart 5-7: Variation of Indoor CO level with time

5.1.5. Temperature

When consider relationships between indoor temperature and vegetation cover or indoor temperature and distance from main road there are no clear relationship between them. Correlation coefficients, ie 0.12 for indoor temperature and vegetation cover and -0.08 for indoor temperature and distance from main road show very weak relationships.

These relationships has not shown because of the indoor temperature is directly affected by the outdoor temperature. Therefore the difference in indoor and outdoor temperature (Indoor temperature – Outdoor temperature) was considered in the comparison. Chart 5-8 shows the variation of indoor temperature difference compared to outdoor with time. In site 1, the maximum temperature difference observed is 1.1^0C. Site 2 has the highest temperature difference of 2.24^0C having a higher temperature inside than that of outdoor throughout the day. When study the correlation between Indoor temperature- Outdoor temperature and vegetation cover, it shows strong relationship between them with correlation coefficient of -0.81. Thus a reduction of temperature was observed in the best case scenario compared to the worst case scenario with respect to presence of vegetative cover. Thus it is noticed that by introducing the surrounding vegetation, comfort level inside the building can be improved.

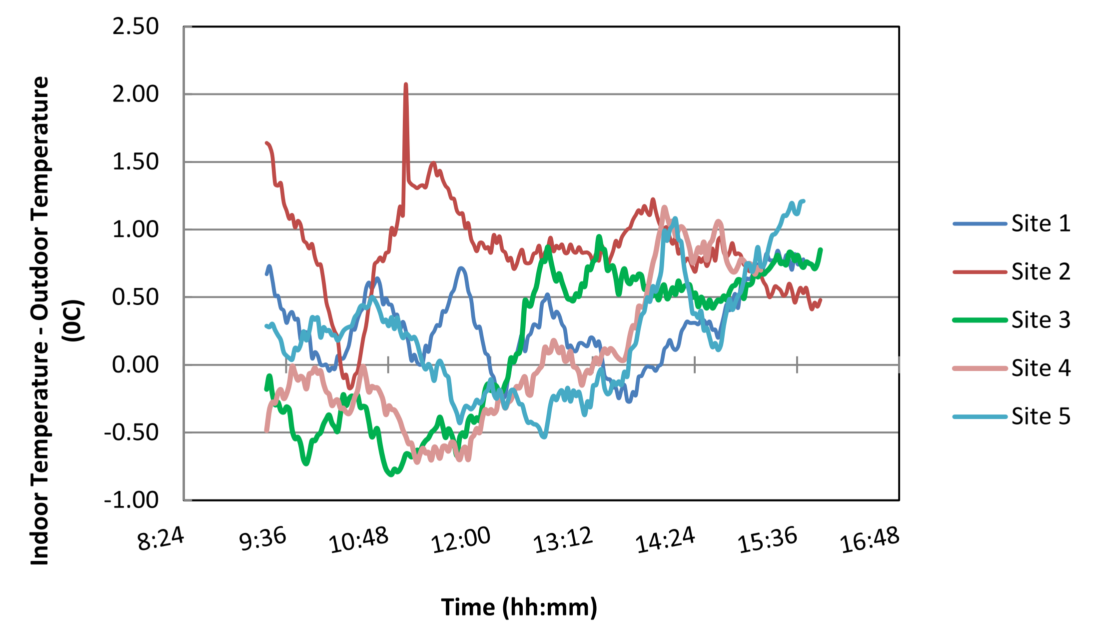


Chart 5-8: Variation of Indoor-outdoor temperature difference with time

5.2. Thermal Comfort

Although thermal sensation varies from person to person, it is considered 80% acceptable comfort zone for the naturally ventilated buildings as in the psychometric chart. The only site 01 within the comfort zone indicates that the selected suburb area has thermally discomfort and vegetated areas have some deviations towards the thermal neutrality.

5.3. Results of Questionnaire Survey

The Questionnaire survey was conducted to find the causes for air pollution and thermal discomfort exist in the indoor environment and investigate the health and wellbeing of the occupants. The data received from 22 occupants in selected 5 residential buildings can be generalized to view the environmental condition in a suburb.

According to the results, 100% of houses are now using the gas cookers for cooking purposes. Site 01 and site 04 have wooden hearth and site 03 has kerosene cooker in addition to the gas cooker. However several undesirable gases generated from the gas cooker contribute to environmental degradation. 40% of gas cooker users, ie site 02 and site 05 have not a chimney in their kitchen. The kitchens without a chimney enhance the issue. This is a prominent reason for having more undesirable gases like NO_2 and CO in site 02.

The types of building materials cause not only air pollution but also thermal discomfort. 60% of houses, ie site 01, site 03 and site 04 were built by brick walls and others were built by cement blocks. Bricks can maintain the inside cooler than cement blocks because of their high thermal capacity. When consider the roofing material 60% roofs, ie site 02, site 03 and site 05 are asbestos sheets while only site 04 has clay tile. Even though only 60% of houses have ceilings they all are asbestos sheets. Asbestos sheets create heat inside the building. It causes to increase the thermal discomfort in the area.

40% of occupants use air freshners and 20% uses body or hair spray and insecticide. No one use chemical fertilizer for their gardening. These type of household materials add more volatile organic matters to the environment. Although according to the results present usage is low, the trend may increase in future. It negatively affect to the environment.

According to the results, sore throat and runny nose are prominent in the area. It mainly cause due to particular matters. However the highest percentage of symptoms is also lower than 30%. It shows the health condition of the occupants is still in better and this area has acceptable level of air quality.

5.4. Control measures of high concentrated air pollutants

5.4.1. Particular matters (PM 2.5) Concentration

Inhaled small fine particles have been deeply penetrating to the lungs and have caused serious health risk. According to this study site 2 and site 4 shows comparatively high level of particular matter concentrations. The following methods can be suggested to control the amount of particles in the indoor air.

- Site 2
  - Close the opening that is directly open to the main road.
  - Plant middle height trees at available places near the building.
  - Place pots of indoor plants at daytime inside the building.
  - Cover the interior of ceiling material by painting.
  - Make attention to avoid damage of ceiling and roofing material.

- Site 4
  - Make a thick green fence in front of the building.
  - Close windows that have directly opened to the main road at peak time of traffic.

5.4.2. CO Concentration

The main source of CO is emissions of motor vehicles due to fuel combustion and emission of kitchen. Only occupants in site 2 has continuous expose to CO. The following suggestions can be proposed to minimize the exposure.

- Site 2
  - Construct a chimney at the kitchen.
  - Open all openings in the kitchen open to outside at cooking time.
  - Close the opening that is directly open to the main road.
  - Use CO detecting meter to make aware the inside CO level.

6. CHAPTER SIX: CONCLUSIONS & RECOMMENDATIONS

6.1. CONCLUSION

The indoor air quality and thermal comfort levels in the residential buildings in suburbs have been evaluated to identify the effect of rapid urbanization in the vicinity. It can be concluded that the air quality in the chosen suburb is still in the acceptable range except for peaking of $PM_{2.5}$ concentration from time to time.

The findings of this study show that significant relationships between indoor air quality level and microclimatic features, as follows:

- Indoor CO_2 level decrease with the vegetation cover
- Indoor/Outdoor CO_2 level decrease with vegetation cover
- Indoor CO_2 level strongly decline with the level of indoor air circulation (Ventilation)
- Indoor $PM_{2.5}$ concentration decrease with the vegetation cover and distance from the main road
- Indoor and Outdoor Temperature difference decrease with the vegetation

It also shows the indoor air quality and thermal comfort in ecofriendly buildings are still being satisfied.

As well the selected suburb is moving towards the thermal dissatisfaction parallel with the urbanization. The areas with better micro-climatic features such as vegetation, water bodies still have thermally comfort.

This clearly indicates that there is a risk of exceeding the desirable air quality levels in the suburbs in the near future if there is no proper plan to manage these residential developments.

6.2. RECOMMENDATIONS

Based on the findings of this study, it can be suggested to have a vegetative cover around buildings to overcome this problem since there is a favourable impact of vegetation on temperature and several air pollutant concentrations. Findings of this research could also be used by the individual house owners for managing thermal comfort in their homes. A reasonable distance from the main road can be proposed with due consideration for the building lines and the street lines for improving air quality.

This study can be further enhanced with;

- Finding a significant tree cover that could act as a barrier for the thermal discomfort and the pollutants generated by the traffic.
- Developing a list of instructions that required to follow by house owners for improving and managing the comfort level inside the house. This can be developed as in building construction period and during occupancy period.
- Built up an empirical relationship between microclimatic conditions and thermal comfort or level of air pollutants. The policy makers can use this empirical relationship for making policy decisions to initiate economic developments.
- Finding a benefitted area from the microclimatic features.
- The type of trees that can reduce the thermal discomfort and pollutants in air.

This research model could be tested for a few other areas to develop the best model. Then the model could give inputs for decision making of the utilization of lands.

7. CHAPTER SEVEN: REFERENCES

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Annex I

Readings of Indoor & Outdoor CO_2 levels and variation of the ratio of (Indoor/Outdoor) CO_2 with time

Readings of Indoor & Outdoor CO_2 levels and variation of the ratio of (Indoor/Outdoor)CO_2 with time

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	(I/O)CO_2	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	(I/O)CO_2	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	(I/O)CO_2	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	(I/O)CO_2	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	(I/O)CO_2
09:22:24				554											
09:24:24				538											
09:26:24				516											
09:28:24				519											
09:30:24		404		514	416	1.236	542	394	1.377					406	
09:32:24		405		514	415	1.239	528	394	1.340					406	
09:34:24		405		515	414	1.244	510	393	1.296					406	
09:36:24		406		513	413	1.241	494	393	1.258					407	
09:38:24		407		509	413	1.234	487	393	1.240					407	
09:40:24		408		502	412	1.219	492	393	1.254					407	
09:42:24	487	408	1.193	499	411	1.213	489	392	1.247				483	407	1.186
09:44:24	490	409	1.199	496	410	1.211	490	392	1.251				482	408	1.183
09:46:24	483	410	1.179	491	409	1.201	488	392	1.246				470	408	1.154
09:48:24	484	410	1.179	486	408	1.190	481	391	1.228				462	408	1.133
09:50:24	482	411	1.172	519	407	1.275	477	391	1.219				498	408	1.219
09:52:24	486	412	1.180	532	407	1.308	486	391	1.244				541	408	1.326
09:54:24	479	413	1.160	511	406	1.260	487	391	1.247				470	409	1.151
09:56:24	484	413	1.171	532	405	1.314	488	390	1.251				453	409	1.107
09:58:24	484	414	1.169	508	404	1.257	506	390	1.297				441	409	1.079
10:00:24	481	414	1.161	492	404	1.219	500	390	1.281		413		445	409	1.089

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$
10:02:24	470	414	1.136	495	405	1.224	492	391	1.259		414		442	409	1.082
10:04:24	472	414	1.141	513	406	1.265	498	392	1.268		414		440	408	1.078
10:06:24	471	414	1.139	514	407	1.265	491	393	1.249		415		444	408	1.089
10:08:24	472	414	1.141	527	407	1.293	499	395	1.264		415		441	408	1.083
10:10:24	480	414	1.159	522	408	1.277	496	396	1.255		416		444	407	1.091
10:12:24	472	414	1.141	507	409	1.239	483	397	1.217	554	416	1.330	445	407	1.095
10:14:24	479	414	1.156	504	410	1.229	478	398	1.200	501	417	1.201	440	407	1.083
10:16:24	475	414	1.146	512	411	1.246	476	399	1.192	484	418	1.159	437	406	1.076
10:18:24	469	414	1.134	510	412	1.239	468	400	1.170	481	418	1.150	440	406	1.085
10:20:24	469	414	1.134	486	413	1.178	468	401	1.167	478	419	1.141	440	405	1.086
10:22:24	478	414	1.154	474	413	1.145	476	403	1.181	476	419	1.134	440	405	1.087
10:24:24	482	414	1.164	492	414	1.188	482	404	1.194	479	420	1.140	499	405	1.232
10:26:24	476	414	1.149	510	415	1.229	476	405	1.175	489	420	1.164	468	404	1.158
10:28:24	474	414	1.144	528	416	1.269	470	406	1.159	489	421	1.162	452	404	1.118
10:30:24	479	414	1.156	538	416	1.294	480	406	1.182	489	421	1.162	446	404	1.105
10:32:24	489	414	1.182	545	416	1.310	483	406	1.190	483	421	1.148	440	404	1.089
10:34:24	488	414	1.179	531	417	1.274	480	405	1.183	479	420	1.140	440	404	1.089
10:36:24	486	414	1.175	517	417	1.241	486	405	1.200	483	420	1.151	443	404	1.096
10:38:24	486	414	1.175	524	417	1.255	489	405	1.208	486	419	1.160	447	405	1.106
10:40:24	483	414	1.167	518	417	1.242	488	405	1.207	483	419	1.154	443	405	1.095
10:42:24	435	414	1.052	517	418	1.238	479	404	1.184	480	418	1.148	429	405	1.059
10:44:24	422	414	1.022	584	418	1.397	479	404	1.185	484	418	1.159	432	405	1.066

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	(I/O)CO_2	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	(I/O)CO_2	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	(I/O)CO_2	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	(I/O)CO_2	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	(I/O)CO_2
10:46:24	438	413	1.060	536	418	1.282	492	404	1.219	493	417	1.183	425	405	1.048
10:48:24	498	413	1.204	526	419	1.256	492	403	1.220	488	417	1.172	422	405	1.042
10:50:24	453	413	1.095	515	419	1.230	481	403	1.193	484	416	1.163	428	405	1.055
10:52:24	440	413	1.065	510	419	1.217	474	403	1.175	479	416	1.152	430	406	1.060
10:54:24	439	413	1.063	503	419	1.199	476	403	1.181	484	415	1.166	422	406	1.041
10:56:24	432	413	1.045	495	420	1.180	481	402	1.195	477	415	1.150	435	406	1.072
10:58:24	435	413	1.053	498	420	1.185	482	402	1.199	476	414	1.149	432	406	1.064
11:00:24	435	413	1.053	531	420	1.264	485	402	1.206	485	414	1.172	425	406	1.046
11:02:24	435	413	1.053	563	420	1.342	489	402	1.216	488	414	1.178	422	406	1.040
11:04:24	416	413	1.007	600	419	1.430	492	402	1.224	492	415	1.187	420	406	1.035
11:06:24	423	413	1.024	545	419	1.302	475	402	1.179	493	415	1.188	417	406	1.027
11:08:24	429	414	1.037	522	419	1.246	465	403	1.156	501	416	1.204	430	406	1.058
11:10:24	426	414	1.029	529	418	1.264	465	403	1.155	508	416	1.221	428	406	1.052
11:12:24	429	414	1.036	532	418	1.273	463	403	1.150	506	417	1.214	416	406	1.024
11:14:24	438	414	1.058	551	418	1.319	465	403	1.154	498	417	1.193	413	407	1.016
11:16:24	432	414	1.043	535	417	1.283	463	403	1.149	488	417	1.169	416	407	1.024
11:18:24	432	414	1.042	522	417	1.251	464	403	1.151	484	418	1.158	421	407	1.036
11:20:24	423	414	1.022	514	416	1.235	477	403	1.182	483	418	1.155	419	407	1.031
11:22:24	431	415	1.039	510	416	1.226	479	404	1.186	484	419	1.156	419	407	1.031
11:24:24	431	415	1.039	505	416	1.214	486	404	1.204	484	419	1.155	421	407	1.036
11:26:24	436	415	1.051	507	415	1.220	479	404	1.185	484	420	1.153	417	407	1.025
11:28:24	439	415	1.058	504	415	1.214	472	404	1.170	486	420	1.157	416	407	1.023

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$
11:30:24	430	415	1.035	511	415	1.232	479	404	1.185	476	420	1.132	419	407	1.030
11:32:24	428	415	1.031	511	415	1.233	465	404	1.151	476	420	1.133	422	407	1.039
11:34:24	429	415	1.033	511	414	1.234	465	404	1.151	485	419	1.157	433	406	1.065
11:36:24	423	415	1.021	505	414	1.220	460	404	1.139	479	419	1.143	425	406	1.045
11:38:24	433	415	1.044	501	413	1.211	463	404	1.146	492	419	1.176	422	406	1.041
11:40:24	438	415	1.056	504	413	1.220	464	404	1.149	517	418	1.237	423	406	1.044
11:42:24	429	415	1.034	502	412	1.216	461	404	1.141	496	418	1.188	439	405	1.083
11:44:24	425	415	1.024	522	412	1.266	462	404	1.144	487	418	1.167	447	405	1.105
11:46:24	427	414	1.029	528	412	1.282	464	404	1.149	487	417	1.168	448	405	1.108
11:48:24	427	414	1.030	532	411	1.294	460	404	1.139	484	417	1.161	438	404	1.083
11:50:24	437	414	1.055	525	411	1.277	457	404	1.131	482	416	1.157	440	404	1.089
11:52:24	440	414	1.063	527	410	1.284	454	404	1.123	479	416	1.151	446	404	1.105
11:54:24	432	414	1.043	519	410	1.267	463	404	1.146	477	416	1.147	445	404	1.104
11:56:24	432	414	1.043	522	409	1.274	463	404	1.146	487	415	1.173	443	403	1.099
11:58:24	426	414	1.028	513	409	1.255	458	404	1.133	490	415	1.181	450	403	1.115
12:00:24	433	414	1.046	496	409	1.214	450	404	1.113	502	415	1.209	458	403	1.136
12:02:24	440	414	1.064	496	409	1.213	454	404	1.123	499	415	1.201	447	403	1.109
12:04:24	438	414	1.059	498	410	1.214	463	404	1.146	486	415	1.171	431	404	1.067
12:06:24	423	413	1.024	500	410	1.218	469	404	1.162	483	415	1.164	434	404	1.074
12:08:24	427	413	1.033	506	411	1.232	465	404	1.151	482	415	1.161	425	404	1.050
12:10:24	423	413	1.026	530	411	1.289	457	404	1.131	485	415	1.169	427	405	1.054
12:12:24	438	413	1.061	543	412	1.320	456	404	1.128	487	415	1.174	430	405	1.061

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$
12:14:24	433	413	1.049	528	412	1.281	455	404	1.126	489	415	1.179	418	406	1.031
12:16:24	430	412	1.042	523	412	1.267	454	404	1.123	492	415	1.186	422	406	1.041
12:18:24	421	412	1.023	524	413	1.268	458	404	1.133	490	415	1.181	428	406	1.053
12:20:24	427	412	1.036	520	413	1.259	472	404	1.170	495	415	1.194	429	407	1.054
12:22:24	434	412	1.054	506	414	1.223	481	404	1.190	486	415	1.171	435	407	1.069
12:24:24	438	411	1.065	518	414	1.252	469	404	1.162	481	415	1.159	442	407	1.086
12:26:24	431	411	1.048	524	415	1.263	464	404	1.149	483	415	1.164	434	408	1.064
12:28:24	439	411	1.068	509	415	1.226	469	404	1.162	485	415	1.169	428	408	1.048
12:30:24	438	411	1.066	507	415	1.221	474	404	1.172	488	415	1.176	415	408	1.017
12:32:24	435	411	1.058	509	415	1.226	477	404	1.180	494	415	1.191	418	408	1.025
12:34:24	439	411	1.068	502	415	1.208	470	404	1.165	498	415	1.198	421	408	1.033
12:36:24	433	411	1.053	501	416	1.205	466	404	1.155	493	415	1.188	417	408	1.023
12:38:24	433	411	1.053	516	416	1.242	469	404	1.163	491	416	1.182	411	408	1.007
12:40:24	427	411	1.038	506	416	1.216	468	404	1.160	487	416	1.172	416	408	1.020
12:42:24	433	411	1.053	512	416	1.230	467	404	1.158	489	416	1.176	418	408	1.025
12:44:24	427	411	1.038	522	417	1.252	469	404	1.163	499	416	1.198	414	408	1.015
12:46:24	425	411	1.033	520	417	1.249	470	403	1.166	502	416	1.206	412	408	1.010
12:48:24	425	411	1.033	522	417	1.251	472	403	1.171	494	416	1.188	435	408	1.066
12:50:24	426	411	1.035	529	417	1.268	466	403	1.156	494	416	1.187	422	408	1.035
12:52:24	422	411	1.028	518	417	1.242	464	403	1.151	489	417	1.174	421	408	1.033
12:54:24	413	411	1.005	511	418	1.224	469	403	1.164	491	417	1.179	423	408	1.038
12:56:24	429	411	1.043	523	418	1.251	469	403	1.164	492	417	1.181	422	408	1.035

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$
12:58:24	425	411	1.033	529	418	1.265	459	403	1.139	488	417	1.171	422	408	1.035
13:00:24	427	411	1.038	532	418	1.273	455	403	1.128	480	417	1.151	451	408	1.104
13:02:24	429	411	1.043	527	417	1.262	457	403	1.133	479	417	1.147	430	408	1.053
13:04:24	432	411	1.051	515	417	1.236	450	403	1.115	476	418	1.139	419	408	1.028
13:06:24	423	411	1.030	517	416	1.243	451	403	1.117	485	418	1.161	412	408	1.010
13:08:24	425	411	1.033	517	416	1.244	447	404	1.109	489	418	1.170	421	408	1.034
13:10:24	432	411	1.051	509	415	1.226	450	404	1.114	490	418	1.172	419	408	1.029
13:12:24	429	411	1.043	500	415	1.205	452	404	1.118	494	419	1.181	412	408	1.011
13:14:24	430	411	1.046	506	414	1.222	456	404	1.128	491	419	1.172	412	408	1.011
13:16:24	432	411	1.051	510	413	1.234	461	404	1.141	492	419	1.174	403	407	0.988
13:18:24	439	411	1.068	501	413	1.213	460	404	1.138	498	420	1.186	405	407	0.993
13:20:24	434	411	1.056	494	412	1.199	452	404	1.117	503	420	1.197	409	407	1.004
13:22:24	440	411	1.071	503	412	1.221	460	405	1.137	499	420	1.187	408	407	1.001
13:24:24	437	411	1.063	513	411	1.248	457	405	1.129	500	420	1.188	402	407	0.986
13:26:24	440	411	1.071	514	411	1.252	455	405	1.123	499	421	1.185	409	407	1.004
13:28:24	440	411	1.071	507	410	1.236	454	405	1.120	500	421	1.187	418	407	1.028
13:30:24	434	411	1.056	504	410	1.229	452	405	1.115	495	421	1.177	409	407	1.005
13:32:24	431	411	1.049	503	410	1.226	456	405	1.125	493	421	1.173	409	407	1.005
13:34:24	429	411	1.044	490	410	1.195	452	405	1.115	508	420	1.208	408	407	1.003
13:36:24	430	410	1.047	498	410	1.213	451	405	1.113	498	420	1.184	406	407	0.998
13:38:24	432	410	1.053	500	410	1.218	448	405	1.107	489	420	1.165	411	406	1.011
13:40:24	440	410	1.074	496	410	1.210	450	405	1.110	488	420	1.163	441	406	1.086

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$
13:42:24	433	410	1.056	492	410	1.199	451	405	1.113	489	419	1.167	434	406	1.068
13:44:24	431	410	1.052	491	411	1.197	455	405	1.123	491	419	1.172	429	406	1.056
13:46:24	430	409	1.050	492	411	1.199	450	405	1.110	487	419	1.163	418	406	1.031
13:48:24	440	409	1.076	488	411	1.189	457	405	1.128	483	418	1.154	418	406	1.031
13:50:24	430	409	1.051	482	411	1.173	456	405	1.125	483	418	1.155	412	406	1.016
13:52:24	433	409	1.059	485	411	1.181	459	405	1.133	484	418	1.158	413	405	1.019
13:54:24	431	408	1.055	477	411	1.160	457	405	1.128	476	418	1.139	412	405	1.017
13:56:24	425	408	1.040	481	411	1.170	457	405	1.128	481	417	1.152	414	405	1.022
13:58:24	425	408	1.040	483	411	1.175	455	405	1.123	491	417	1.178	443	405	1.095
14:00:24	433	408	1.061	475	411	1.155	453	405	1.118	495	417	1.188	431	405	1.064
14:02:24	437	408	1.070	470	412	1.142	457	405	1.128	491	417	1.178	419	405	1.035
14:04:24	436	409	1.067	475	413	1.150	459	405	1.134	483	417	1.158	411	405	1.014
14:06:24	432	409	1.056	472	414	1.142	459	405	1.134	487	417	1.167	433	405	1.068
14:08:24	426	409	1.040	478	414	1.153	454	404	1.122	481	417	1.152	434	406	1.070
14:10:24	440	409	1.075	477	415	1.148	454	404	1.122	486	417	1.165	428	406	1.054
14:12:24	438	410	1.069	479	416	1.150	462	404	1.143	481	417	1.152	419	406	1.033
14:14:24	430	410	1.048	483	417	1.158	465	404	1.151	472	418	1.132	418	406	1.030
14:16:24	438	410	1.068	486	418	1.163	462	404	1.144	472	418	1.132	419	406	1.032
14:18:24	439	411	1.070	493	419	1.178	459	404	1.137	470	418	1.126	417	406	1.027
14:20:24	438	411	1.066	491	420	1.171	464	404	1.150	464	418	1.111	429	406	1.055
14:22:24	439	411	1.068	487	420	1.159	467	403	1.158	467	418	1.118	422	407	1.039
14:24:24	435	411	1.057	489	421	1.161	479	403	1.187	472	418	1.131	418	407	1.028

Annex - I

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$
14:26:24	435	412	1.056	486	422	1.151	486	403	1.206	476	418	1.138	417	407	1.025
14:28:24	433	412	1.051	481	423	1.137	479	403	1.188	475	418	1.135	446	407	1.097
14:30:24	429	412	1.040	483	423	1.142	484	403	1.201	475	418	1.135	442	407	1.087
14:32:24	435	412	1.057	483	424	1.139	491	403	1.219	472	418	1.130	429	407	1.054
14:34:24	437	411	1.063	480	425	1.128	483	403	1.197	474	418	1.132	417	406	1.027
14:36:24	417	411	1.016	483	426	1.132	476	403	1.179	470	419	1.124	411	406	1.013
14:38:24	425	410	1.035	486	428	1.137	478	404	1.184	475	419	1.133	405	405	0.999
14:40:24	427	410	1.042	487	429	1.136	477	404	1.181	481	419	1.147	401	405	0.989
14:42:24	439	409	1.074	489	430	1.138	486	404	1.204	486	419	1.159	405	404	1.001
14:44:24	440	409	1.077	500	431	1.159	472	404	1.170	487	420	1.161	405	404	1.002
14:46:24	434	408	1.063	506	432	1.171	472	404	1.169	486	420	1.158	411	404	1.018
14:48:24	435	408	1.067	500	433	1.153	478	404	1.182	484	420	1.152	412	403	1.022
14:50:24	440	407	1.081	501	434	1.152	483	404	1.194	496	420	1.182	409	403	1.015
14:52:24	440	407	1.083	498	436	1.142	483	405	1.194	514	420	1.223	410	402	1.019
14:54:24	440	406	1.084	498	437	1.139	484	405	1.196	498	421	1.183	410	402	1.020
14:56:24	440	406	1.085	499	438	1.139	484	405	1.195	485	421	1.153	411	401	1.024
14:58:24	440	405	1.087	493	439	1.124	487	405	1.203	486	421	1.155	409	401	1.020
15:00:24	438	405	1.082	489	439	1.114	487	405	1.203	481	421	1.142	411	401	1.025
15:02:24	440	405	1.086	489	439	1.114	485	405	1.198	489	420	1.164	410	402	1.021
15:04:24	440	406	1.085	489	439	1.114	476	405	1.175	486	420	1.158	411	402	1.022
15:06:24	440	406	1.083	483	439	1.100	467	405	1.155	482	419	1.150	408	403	1.013
15:08:24	439	407	1.080	486	439	1.107	462	404	1.142	475	418	1.135	407	403	1.009

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	$(I/O)CO_2$
15:10:24	440	407	1.081	488	439	1.112	462	404	1.143	468	417	1.122	405	404	1.003
15:12:24	438	408	1.075	487	439	1.110	463	404	1.146	468	417	1.124	399	404	0.989
15:14:24	430	408	1.053	492	439	1.121	460	404	1.139	465	416	1.118	406	405	1.003
15:16:24	440	408	1.078	500	439	1.138	471	404	1.167	446	415	1.075	399	405	0.986
15:18:24	441	409	1.079	517	439	1.178	472	404	1.170	435	415	1.049	405	406	0.998
15:20:24	433	409	1.058	512	439	1.167	482	404	1.194	428	414	1.033	423	406	1.043
15:22:24	429	410	1.046	523	439	1.190	481	403	1.192	432	413	1.045	420	407	1.034
15:24:24	435	410	1.060	522	439	1.188	491	403	1.218	437	412	1.060	411	407	1.010
15:26:24	440	411	1.072	534	439	1.216	506	403	1.255	437	412	1.061	406	408	0.996
15:28:24	440	411	1.071	540	439	1.231	491	403	1.219	439	411	1.068	403	408	0.987
15:30:24	439	411	1.068	552	439	1.257	479	403	1.188	431	411	1.048	403	408	0.987
15:32:24	435	411	1.058	552	438	1.258	484	403	1.201	436	411	1.061	402	408	0.984
15:34:24	435	411	1.058	552	438	1.260	477	403	1.184	421	411	1.026	399	408	0.979
15:36:24	440	411	1.070	548	437	1.252	470	403	1.168	420	411	1.024	402	408	0.984
15:38:24	438	412	1.064	537	437	1.230	471	402	1.171	421	410	1.027	405	408	0.992
15:40:24	437	412	1.061	535	436	1.227	478	402	1.187	428	410	1.042	410	408	1.005
15:42:24	427	412	1.036	562	436	1.291	472	402	1.175	440	410	1.073	411	408	1.007
15:44:24	429	412	1.040	557	435	1.280	472	402	1.175	435	410	1.061	412	408	1.010
15:46:24	433	412	1.050	543	434	1.251	472	402	1.176	441	410	1.076	417	408	1.023
15:48:24	437	412	1.060	559	434	1.289	469	402	1.168	440	410	1.074	415	408	1.017
15:50:24	436	412	1.057	518	433	1.196	476	402	1.184	438	410	1.070	405	408	0.992
15:52:24	440	413	1.067	518	433	1.198	476	401	1.185	431	409	1.052	405	408	0.992

Annex - I

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	(I/O)CO_2	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	(I/O)CO_2	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	(I/O)CO_2	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	(I/O)CO_2	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	(I/O)CO_2
15:54:24	440	413	1.066	513	432	1.187	474	401	1.180	427	409	1.042	406	408	0.994
15:56:24	440	413	1.066	511	432	1.184	479	401	1.193	430	409	1.050	406	408	0.994
15:58:24	441	413	1.068	517	431	1.200	485	401	1.209	440	409	1.076	406	408	0.994
16:00:24	443	413	1.073	516	431	1.198	485	401	1.209	447	409	1.094	404	408	0.989
16:02:24	440			527			486			446			405		
16:04:24	440			514			491			453			403		
16:06:24	438			510			478			457			407		
16:08:24	431			505			470			451			413		
16:10:24	440			505			462			456			411		
16:12:24	440			508			464			454			409		
16:14:24	440			518			508			452			406		
16:16:24	440			513						456			408		
16:18:24	440			517						452			401		
16:20:24	440			535						446			403		
16:22:24	438			519						451			403		
16:24:24	443			578						451			410		
16:26:24	442			577									416		
	442												419		
AVG	**441**	**412**	**1.071**	**510**	**419**	**1.219**	**472**	**402**	**1.173**	**480**	**417**	**1.151**	**422**	**406**	**1.048**

Annex II

NO_2 readings from Air Quality Monitor

NO_2 Reading from Air Quality Monitor

Time	NO_2 (ppm)				
	Site 1	Site 2	Site 3	Site 4	Site 5
9:22 AM		0.026			
9:24 AM		0.025			
9:26 AM		0.027			
9:28 AM		0.024			
9:30 AM		0.025	0.029		
9:32 AM		0.025	0.024		
9:34 AM		0.026	0.024		
9:36 AM		0.026	0.024		
9:38 AM		0.027	0.024		
9:40 AM		0.028	0.023		
9:42 AM	0.023	0.030	0.023		0.025
9:44 AM	0.024	0.031	0.023		0.024
9:46 AM	0.027	0.031	0.024		0.022
9:48 AM	0.026	0.031	0.021		0.020
9:50 AM	0.028	0.032	0.025		0.022
9:52 AM	0.027	0.030	0.025		0.022
9:54 AM	0.030	0.031	0.023		0.022
9:56 AM	0.029	0.032	0.025		0.020
9:58 AM	0.028	0.031	0.025		0.022
10:00 AM	0.030	0.031	0.026		0.023
10:02 AM	0.029	0.032	0.025		0.022
10:04 AM	0.030	0.034	0.024		0.025
10:06 AM	0.028	0.033	0.024		0.024
10:08 AM	0.030	0.032	0.026		0.023
10:10 AM	0.029	0.032	0.024		0.023
10:12 AM	0.031	0.032	0.025	0.023	0.025
10:14 AM	0.031	0.033	0.025	0.021	0.026
10:16 AM	0.031	0.032	0.024	0.020	0.024
10:18 AM	0.030	0.030	0.025	0.019	0.023
10:20 AM	0.031	0.032	0.027	0.018	0.023
10:22 AM	0.030	0.032	0.027	0.018	0.024
10:24 AM	0.032	0.034	0.025	0.018	0.024
10:26 AM	0.032	0.032	0.024	0.018	0.024
10:28 AM	0.032	0.031	0.026	0.018	0.023
10:30 AM	0.033	0.033	0.029	0.018	0.023
10:32 AM	0.032	0.031	0.026	0.017	0.024
10:34 AM	0.031	0.032	0.026	0.020	0.025
10:36 AM	0.030	0.033	0.027	0.020	0.024
10:38 AM	0.030	0.032	0.026	0.019	0.024
10:40 AM	0.031	0.032	0.026	0.019	0.025

Time	NO_2 (ppm)				
	Site 1	Site 2	Site 3	Site 4	Site 5
10:42 AM	0.032	0.032	0.026	0.019	0.025
10:44 AM	0.029	0.034	0.027	0.019	0.024
10:46 AM	0.032	0.031	0.027	0.020	0.023
10:48 AM	0.033	0.031	0.028	0.021	0.024
10:50 AM	0.032	0.032	0.023	0.019	0.025
10:52 AM	0.031	0.032	0.027	0.019	0.024
10:54 AM	0.033	0.031	0.028	0.020	0.026
10:56 AM	0.033	0.030	0.028	0.019	0.024
10:58 AM	0.032	0.030	0.027	0.019	0.024
11:00 AM	0.033	0.030	0.028	0.019	0.024
11:02 AM	0.036	0.032	0.028	0.019	0.025
11:04 AM	0.036	0.033	0.028	0.021	0.027
11:06 AM	0.038	0.029	0.027	0.020	0.026
11:08 AM	0.034	0.034	0.029	0.023	0.026
11:10 AM	0.035	0.033	0.027	0.023	0.025
11:12 AM	0.035	0.033	0.028	0.023	0.025
11:14 AM	0.034	0.032	0.029	0.023	0.025
11:16 AM	0.034	0.032	0.030	0.022	0.025
11:18 AM	0.035	0.035	0.029	0.025	0.026
11:20 AM	0.036	0.033	0.029	0.022	0.025
11:22 AM	0.034	0.033	0.029	0.020	0.026
11:24 AM	0.036	0.034	0.029	0.019	0.027
11:26 AM	0.039	0.034	0.027	0.020	0.026
11:28 AM	0.039	0.033	0.029	0.020	0.027
11:30 AM	0.034	0.033	0.028	0.019	0.027
11:32 AM	0.038	0.033	0.028	0.020	0.027
11:34 AM	0.037	0.034	0.027	0.021	0.027
11:36 AM	0.038	0.034	0.027	0.020	0.027
11:38 AM	0.037	0.036	0.029	0.022	0.027
11:40 AM	0.034	0.034	0.026	0.021	0.027
11:42 AM	0.034	0.034	0.028	0.021	0.026
11:44 AM	0.034	0.035	0.030	0.021	0.024
11:46 AM	0.031	0.034	0.030	0.020	0.025
11:48 AM	0.032	0.034	0.025	0.021	0.025
11:50 AM	0.037	0.035	0.030	0.022	0.026
11:52 AM	0.036	0.034	0.031	0.020	0.026
11:54 AM	0.035	0.032	0.027	0.022	0.025
11:56 AM	0.034	0.032	0.028	0.021	0.024
11:58 AM	0.032	0.032	0.027	0.021	0.024
12:00 PM	0.033	0.033	0.029	0.021	0.024
12:02 PM	0.033	0.033	0.030	0.022	0.022
12:04 PM	0.034	0.036	0.027	0.020	0.024

Time	NO_2 (ppm)				
	Site 1	Site 2	Site 3	Site 4	Site 5
12:06 PM	0.033	0.035	0.027	0.021	0.025
12:08 PM	0.033	0.034	0.028	0.022	0.026
12:10 PM	0.033	0.032	0.027	0.021	0.026
12:12 PM	0.034	0.032	0.027	0.021	0.024
12:14 PM	0.033	0.032	0.026	0.020	0.024
12:16 PM	0.033	0.031	0.029	0.019	0.026
12:18 PM	0.032	0.032	0.028	0.021	0.024
12:20 PM	0.033	0.029	0.028	0.021	0.025
12:22 PM	0.036	0.032	0.027	0.020	0.023
12:24 PM	0.039	0.031	0.026	0.020	0.023
12:26 PM	0.037	0.031	0.026	0.020	0.020
12:28 PM	0.038	0.032	0.028	0.021	0.019
12:30 PM	0.035	0.031	0.029	0.021	0.019
12:32 PM	0.036	0.031	0.025	0.022	0.022
12:34 PM	0.034	0.034	0.022	0.023	0.020
12:36 PM	0.036	0.031	0.025	0.023	0.020
12:38 PM	0.034	0.032	0.031	0.023	0.021
12:40 PM	0.032	0.033	0.025	0.021	0.021
12:42 PM	0.032	0.033	0.028	0.021	0.018
12:44 PM	0.033	0.032	0.029	0.022	0.021
12:46 PM	0.034	0.032	0.029	0.022	0.019
12:48 PM	0.034	0.033	0.027	0.024	0.020
12:50 PM	0.036	0.032	0.025	0.024	0.019
12:52 PM	0.037	0.030	0.028	0.023	0.020
12:54 PM	0.036	0.032	0.027	0.022	0.018
12:56 PM	0.036	0.032	0.029	0.022	0.019
12:58 PM	0.034	0.031	0.025	0.021	0.023
1:00 PM	0.034	0.031	0.026	0.021	0.019
1:02 PM	0.033	0.031	0.026	0.018	0.020
1:04 PM	0.033	0.031	0.028	0.021	0.021
1:06 PM	0.034	0.031	0.026	0.019	0.022
1:08 PM	0.032	0.033	0.027	0.019	0.020
1:10 PM	0.034	0.032	0.030	0.019	0.019
1:12 PM	0.036	0.030	0.029	0.020	0.021
1:14 PM	0.036	0.033	0.029	0.018	0.020
1:16 PM	0.035	0.033	0.030	0.020	0.019
1:18 PM	0.036	0.033	0.030	0.019	0.020
1:20 PM	0.036	0.034	0.028	0.019	0.020
1:22 PM	0.034	0.036	0.028	0.020	0.019
1:24 PM	0.033	0.033	0.028	0.019	0.021
1:26 PM	0.034	0.033	0.029	0.020	0.021
1:28 PM	0.034	0.033	0.030	0.019	0.021

Time	NO_2 (ppm)				
	Site 1	Site 2	Site 3	Site 4	Site 5
1:30 PM	0.031	0.033	0.030	0.020	0.022
1:32 PM	0.031	0.034	0.030	0.020	0.022
1:34 PM	0.033	0.034	0.031	0.019	0.020
1:36 PM	0.033	0.034	0.030	0.019	0.021
1:38 PM	0.032	0.034	0.029	0.018	0.021
1:40 PM	0.033	0.032	0.030	0.018	0.019
1:42 PM	0.032	0.032	0.030	0.019	0.017
1:44 PM	0.032	0.034	0.030	0.019	0.023
1:46 PM	0.034	0.034	0.030	0.018	0.021
1:48 PM	0.037	0.033	0.028	0.017	0.019
1:50 PM	0.032	0.033	0.029	0.020	0.021
1:52 PM	0.033	0.034	0.029	0.020	0.022
1:54 PM	0.033	0.034	0.029	0.019	0.021
1:56 PM	0.033	0.033	0.029	0.021	0.021
1:58 PM	0.032	0.033	0.030	0.020	0.020
2:00 PM	0.033	0.035	0.031	0.020	0.021
2:02 PM	0.035	0.033	0.030	0.019	0.021
2:04 PM	0.034	0.035	0.030	0.020	0.021
2:06 PM	0.033	0.035	0.029	0.020	0.023
2:08 PM	0.032	0.035	0.030	0.021	0.020
2:10 PM	0.032	0.034	0.030	0.019	0.022
2:12 PM	0.030	0.035	0.031	0.020	0.020
2:14 PM	0.032	0.034	0.029	0.020	0.021
2:16 PM	0.031	0.036	0.029	0.020	0.021
2:18 PM	0.033	0.037	0.030	0.018	0.022
2:20 PM	0.034	0.038	0.030	0.020	0.021
2:22 PM	0.035	0.036	0.029	0.021	0.021
2:24 PM	0.031	0.036	0.030	0.021	0.021
2:26 PM	0.032	0.035	0.030	0.020	0.021
2:28 PM	0.032	0.035	0.028	0.021	0.021
2:30 PM	0.033	0.034	0.028	0.022	0.021
2:32 PM	0.033	0.034	0.030	0.021	0.021
2:34 PM	0.035	0.035	0.029	0.021	0.019
2:36 PM	0.033	0.034	0.029	0.021	0.020
2:38 PM	0.031	0.034	0.028	0.022	0.022
2:40 PM	0.033	0.036	0.029	0.023	0.023
2:42 PM	0.033	0.036	0.030	0.022	0.022
2:44 PM	0.032	0.036	0.029	0.021	0.021
2:46 PM	0.033	0.034	0.029	0.020	0.023
2:48 PM	0.036	0.033	0.028	0.021	0.021
2:50 PM	0.038	0.032	0.028	0.022	0.021
2:52 PM	0.035	0.032	0.028	0.021	0.022

Time	NO_2 (ppm)				
	Site 1	Site 2	Site 3	Site 4	Site 5
2:54 PM	0.035	0.033	0.028	0.017	0.021
2:56 PM	0.035	0.031	0.028	0.018	0.021
2:58 PM	0.033	0.035	0.028	0.020	0.021
3:00 PM	0.033	0.037	0.028	0.020	0.020
3:02 PM	0.034	0.035	0.027	0.020	0.020
3:04 PM	0.034	0.034	0.028	0.019	0.021
3:06 PM	0.033	0.033	0.026	0.018	0.019
3:08 PM	0.032	0.033	0.028	0.019	0.021
3:10 PM	0.031	0.034	0.028	0.021	0.021
3:12 PM	0.032	0.033	0.027	0.022	0.021
3:14 PM	0.034	0.033	0.028	0.021	0.021
3:16 PM	0.034	0.034	0.027	0.022	0.021
3:18 PM	0.033	0.032	0.027	0.021	0.022
3:20 PM	0.033	0.032	0.028	0.022	0.022
3:22 PM	0.033	0.031	0.028	0.021	0.020
3:24 PM	0.033	0.031	0.028	0.022	0.020
3:26 PM	0.032	0.031	0.028	0.022	0.023
3:28 PM	0.031	0.032	0.028	0.021	0.025
3:30 PM	0.032	0.031	0.028	0.021	0.026
3:32 PM	0.031	0.032	0.029	0.021	0.025
3:34 PM	0.031	0.034	0.027	0.021	0.025
3:36 PM	0.032	0.034	0.028	0.020	0.024
3:38 PM	0.031	0.032	0.027	0.021	0.024
3:40 PM	0.030	0.032	0.027	0.022	0.024
3:42 PM	0.034	0.032	0.028	0.023	0.021
3:44 PM	0.032	0.029	0.029	0.022	0.024
3:46 PM	0.032	0.031	0.028	0.022	0.026
3:48 PM	0.033	0.033	0.028	0.022	0.025
3:50 PM	0.034	0.030	0.029	0.021	0.023
3:52 PM	0.032	0.031	0.028	0.021	0.022
3:54 PM	0.033	0.032	0.028	0.021	0.024
3:56 PM	0.032	0.031	0.030	0.022	0.025
3:58 PM	0.030	0.030	0.028	0.022	0.025
4:00 PM	0.032	0.031	0.029	0.022	0.025
4:02 PM	0.031	0.030	0.029	0.022	0.026
4:04 PM	0.031	0.030	0.028	0.021	0.026
4:06 PM	0.030	0.030	0.028	0.022	0.025
4:08 PM	0.031	0.030	0.028	0.022	0.025
4:10 PM	0.032	0.033	0.029	0.022	0.025
4:12 PM	0.032	0.032	0.029	0.022	0.024
4:14 PM	0.030	0.032	0.030	0.022	0.025
4:16 PM	0.030	0.030		0.022	0.024

Time	NO_2 (ppm)				
	Site 1	Site 2	Site 3	Site 4	Site 5
4:18 PM	0.032	0.032		0.022	0.024
4:20 PM	0.032	0.031		0.023	0.024
4:22 PM	0.032	0.033		0.023	0.024
4:24 PM	0.029	0.034		0.023	0.025
4:26 PM	0.029	0.031			0.025
	0.030				0.026
AVG	**0.033**	**0.032**	**0.028**	**0.021**	**0.023**

Annex III

Particulate Matter readings from Real-time Particulate Monitor

Particular Matter Readings from Real-time Particulate Monitor

Time	Site 1	Site 2	Site 3	Site 4	Site 5
9:10 AM					
9:11 AM		0.004			
9:12 AM		0.003			
9:13 AM		0.005			
9:14 AM		0.007			
9:15 AM		0.015			
9:16 AM		0.016			
9:17 AM		0.002			
9:18 AM		0.002			
9:19 AM		0.002			
9:20 AM		0.002			
9:21 AM		0.001			
9:22 AM					
9:23 AM					
9:24 AM					
9:25 AM					
9:26 AM					
9:27 AM					
9:28 AM					
9:29 AM					
9:30 AM					
9:31 AM					
9:32 AM					
9:33 AM					0.029
9:34 AM			0.002		0.011
9:35 AM			0.002		0.002
9:36 AM			0.002		0.002
9:37 AM			0.002		0.002
9:38 AM			0.002		0.002
9:39 AM			0.002		0.002
9:40 AM			0.010		0.002
9:41 AM			0.007		0.002
9:42 AM			0.006		0.002
9:43 AM			0.005		0.002
9:44 AM			0.002		0.002
9:45 AM			0.002		0.002
9:46 AM			0.002		0.002
9:47 AM			0.002	0.022	0.002
9:48 AM			0.002	0.036	0.002
9:49 AM			0.002	0.023	0.002
9:50 AM			0.002	0.011	0.002
9:51 AM			0.002	0.010	0.002
9:52 AM			0.002	0.007	0.002
9:53 AM			0.002	0.005	0.002

Time	Site 1	Site 2	Site 3	Site 4	Site 5
9:54 AM			0.002	0.006	0.002
9:55 AM			0.002	0.003	0.002
9:56 AM			0.002	0.002	0.002
9:57 AM				0.002	0.002
9:58 AM				0.002	0.002
9:59 AM				0.002	0.001
10:00 AM			0.001	0.002	0.001
10:01 AM			0.002	0.003	
10:02 AM			0.002	0.002	
10:03 AM				0.002	
10:04 AM				0.002	
10:05 AM				0.002	
10:06 AM				0.002	
10:07 AM				0.002	
10:08 AM				0.002	
10:09 AM				0.002	
10:10 AM				0.002	
10:11 AM				0.002	
10:12 AM				0.002	
10:13 AM				0.002	
10:14 AM				0.002	
10:15 AM				0.002	
10:16 AM				0.002	
10:17 AM				0.002	
10:18 AM				0.002	
10:19 AM				0.006	
10:20 AM				0.003	
10:21 AM				0.006	
10:22 AM				0.002	
10:23 AM				0.003	
10:24 AM			0.002	0.003	
10:25 AM			0.003	0.002	
10:26 AM			0.002	0.002	
10:27 AM			0.005	0.002	
10:28 AM			0.006	0.002	
10:29 AM			0.002	0.002	
10:30 AM			0.002	0.002	
10:31 AM			0.002	0.002	
10:32 AM			0.002	0.002	
10:33 AM			0.002	0.002	
10:34 AM			0.002	0.002	
10:35 AM			0.002	0.002	
10:36 AM			0.002	0.002	0.002
10:37 AM			0.002	0.002	0.002
10:38 AM			0.002	0.002	0.002
10:39 AM			0.002	0.002	0.002

Time	Site 1	Site 2	Site 3	Site 4	Site 5
10:40 AM			0.002	0.002	0.002
10:41 AM			0.002	0.002	0.002
10:42 AM			0.002	0.002	0.002
10:43 AM			0.002	0.002	0.002
10:44 AM			0.002	0.002	0.002
10:45 AM			0.002	0.002	0.002
10:46 AM			0.002	0.002	0.003
10:47 AM			0.002	0.002	0.005
10:48 AM			0.002	0.002	0.003
10:49 AM			0.002	0.011	0.004
10:50 AM			0.001	0.017	0.002
10:51 AM			0.001	0.022	0.002
10:52 AM				0.020	0.002
10:53 AM				0.008	0.002
10:54 AM			0.017	0.021	0.002
10:55 AM			0.018	0.033	0.002
10:56 AM			0.018	0.070	0.002
10:57 AM			0.011	0.075	0.002
10:58 AM			0.009	0.069	0.002
10:59 AM			0.013	0.052	0.002
11:00 AM			0.009	0.046	0.002
11:01 AM			0.012	0.026	0.002
11:02 AM			0.012	0.012	0.002
11:03 AM		0.004	0.012	0.004	0.002
11:04 AM		0.002	0.025	0.002	0.002
11:05 AM		0.066	0.002	0.002	0.002
11:06 AM		0.043	0.002	0.002	0.010
11:07 AM		0.047	0.002	0.002	0.009
11:08 AM		0.070	0.002	0.002	0.009
11:09 AM	0.002	0.097	0.004	0.002	0.007
11:10 AM	0.002	0.065	0.002	0.002	0.009
11:11 AM	0.018	0.046	0.002	0.002	0.010
11:12 AM	0.026	0.040	0.002	0.002	0.010
11:13 AM	0.032		0.002	0.003	0.005
11:14 AM	0.030	0.088	0.002	0.002	0.009
11:15 AM	0.029	0.015	0.002	0.002	0.009
11:16 AM	0.042	0.003	0.002	0.006	0.007
11:17 AM	0.051	0.002	0.002	0.006	0.006
11:18 AM	0.049	0.002	0.002	0.006	0.008
11:19 AM	0.038	0.002	0.002	0.013	0.009
11:20 AM	0.029	0.002	0.002	0.009	0.010
11:21 AM	0.030	0.002	0.002	0.007	0.005
11:22 AM	0.034	0.021	0.002	0.003	0.009
11:23 AM	0.034	0.032	0.002	0.002	0.003
11:24 AM	0.049	0.082	0.003	0.002	0.002
11:25 AM	0.065	0.041	0.009	0.002	0.002

Time	Site 1	Site 2	Site 3	Site 4	Site 5
11:26 AM	0.052	0.059	0.006	0.002	0.002
11:27 AM	0.046	0.007	0.002	0.002	0.002
11:28 AM	0.047	0.006	0.002	0.002	0.002
11:29 AM	0.043	0.008	0.002	0.002	0.002
11:30 AM	0.036	0.013	0.002	0.002	0.002
11:31 AM	0.025	0.069	0.002	0.002	0.002
11:32 AM	0.016	0.027	0.002	0.002	0.002
11:33 AM	0.008	0.004	0.002	0.002	0.003
11:34 AM	0.004	0.002	0.002	0.002	0.002
11:35 AM	0.002	0.042	0.002	0.002	0.002
11:36 AM	0.002	0.032	0.002	0.002	0.013
11:37 AM	0.002	0.048	0.002	0.002	0.010
11:38 AM	0.010	0.016	0.002	0.002	0.012
11:39 AM	0.018	0.006	0.002	0.002	0.013
11:40 AM	0.024	0.002	0.002	0.002	0.004
11:41 AM	0.008	0.002	0.002	0.002	0.004
11:42 AM	0.005	0.002	0.002	0.002	0.002
11:43 AM	0.002	0.002	0.002	0.002	0.002
11:44 AM	0.002	0.002	0.002	0.002	0.002
11:45 AM	0.002	0.002	0.002	0.002	0.002
11:46 AM	0.002	0.019	0.002	0.002	0.002
11:47 AM	0.002	0.028	0.002	0.002	0.002
11:48 AM	0.002	0.089	0.002	0.002	0.002
11:49 AM	0.002	0.057	0.002	0.009	0.002
11:50 AM	0.002	0.027	0.001	0.008	0.002
11:51 AM	0.002	0.025		0.007	0.005
11:52 AM	0.002	0.022		0.007	0.005
11:53 AM	0.002	0.013		0.002	0.002
11:54 AM	0.002	0.012	0.009	0.002	0.002
11:55 AM	0.002	0.016	0.010	0.002	0.002
11:56 AM	0.002	0.012	0.013	0.002	0.002
11:57 AM	0.002	0.004	0.019	0.002	0.002
11:58 AM	0.002	0.003	0.024	0.002	0.002
11:59 AM	0.002	0.022	0.029	0.002	0.002
12:00 PM	0.002	0.002	0.029	0.002	0.002
12:01 PM	0.002	0.002	0.034	0.002	0.002
12:02 PM	0.002	0.005	0.031	0.002	0.002
12:03 PM	0.002	0.002	0.012	0.002	0.002
12:04 PM	0.002	0.002	0.015	0.002	0.002
12:05 PM	0.002	0.037	0.012	0.002	0.002
12:06 PM	0.002	0.009	0.002	0.002	0.020
12:07 PM	0.002	0.005	0.002	0.002	0.009
12:08 PM	0.002	0.005	0.005	0.002	0.002
12:09 PM	0.002	0.015		0.002	0.008
12:10 PM	0.002	0.003		0.002	0.006
12:11 PM	0.014	0.002		0.002	0.003

Time	Site 1	Site 2	Site 3	Site 4	Site 5
12:12 PM	0.011	0.002		0.002	0.003
12:13 PM	0.006	0.002		0.002	0.002
12:14 PM	0.015	0.018		0.002	0.002
12:15 PM	0.032			0.002	0.002
12:16 PM	0.019	0.091		0.002	0.002
12:17 PM	0.017	0.089		0.002	0.002
12:18 PM	0.034	0.053		0.002	0.002
12:19 PM	0.017	0.012		0.013	0.002
12:20 PM	0.011	0.024		0.013	0.002
12:21 PM	0.006	0.034		0.013	0.002
12:22 PM	0.002	0.034		0.011	0.002
12:23 PM	0.002	0.013		0.007	0.002
12:24 PM	0.002	0.002		0.006	0.002
12:25 PM	0.002	0.002		0.007	0.002
12:26 PM	0.002	0.002		0.008	0.002
12:27 PM	0.002	0.002		0.008	0.002
12:28 PM	0.002	0.002		0.009	0.002
12:29 PM	0.002	0.002		0.005	0.002
12:30 PM	0.002	0.003		0.003	0.002
12:31 PM	0.002	0.002		0.002	0.002
12:32 PM	0.002	0.002		0.003	0.002
12:33 PM	0.002	0.002		0.002	0.002
12:34 PM	0.002	0.002		0.002	0.002
12:35 PM	0.002	0.009		0.002	0.002
12:36 PM	0.002	0.010		0.003	0.009
12:37 PM	0.002	0.016		0.005	0.014
12:38 PM	0.002	0.013		0.003	0.016
12:39 PM	0.002	0.022		0.002	0.015
12:40 PM	0.002	0.021		0.002	0.019
12:41 PM	0.003	0.020		0.006	0.011
12:42 PM	0.002	0.020		0.007	0.009
12:43 PM	0.002	0.013		0.003	0.013
12:44 PM	0.002	0.009		0.002	0.014
12:45 PM	0.002	0.003		0.002	0.014
12:46 PM	0.002	0.002		0.002	0.015
12:47 PM	0.002	0.002		0.002	0.012
12:48 PM	0.002	0.002		0.002	0.009
12:49 PM	0.002	0.002		0.005	0.012
12:50 PM	0.002	0.004		0.005	0.010
12:51 PM	0.002	0.002		0.005	0.011
12:52 PM	0.002	0.002		0.002	0.011
12:53 PM	0.002	0.002		0.003	0.011
12:54 PM	0.002	0.002		0.003	0.009
12:55 PM	0.002	0.002		0.002	0.007
12:56 PM	0.002	0.002		0.002	0.008
12:57 PM	0.002	0.002		0.002	0.007

Time	Site 1	Site 2	Site 3	Site 4	Site 5
12:58 PM	0.002	0.002		0.002	0.005
12:59 PM	0.002	0.002		0.002	0.003
1:00 PM	0.002	0.002		0.002	0.004
1:01 PM	0.002	0.002		0.002	0.002
1:02 PM	0.002	0.002		0.002	0.002
1:03 PM	0.002	0.002		0.002	0.002
1:04 PM	0.002	0.002		0.002	0.002
1:05 PM	0.002	0.014		0.002	0.002
1:06 PM	0.002	0.014		0.002	0.008
1:07 PM	0.002	0.011		0.002	0.011
1:08 PM	0.002	0.003		0.002	0.013
1:09 PM	0.002	0.005		0.002	0.019
1:10 PM	0.002	0.005		0.002	0.025
1:11 PM	0.002	0.006		0.002	0.028
1:12 PM	0.004	0.005		0.002	0.031
1:13 PM	0.005	0.003		0.002	0.026
1:14 PM	0.007	0.002		0.002	0.021
1:15 PM	0.012	0.003		0.002	0.020
1:16 PM	0.011	0.009		0.002	0.018
1:17 PM	0.009	0.011		0.002	0.016
1:18 PM	0.015	0.012		0.002	0.018
1:19 PM	0.027	0.017		0.012	0.018
1:20 PM	0.007	0.017		0.012	0.004
1:21 PM	0.004	0.022		0.017	0.002
1:22 PM	0.002	0.024		0.018	0.004
1:23 PM	0.002	0.024		0.016	0.006
1:24 PM	0.002	0.019		0.006	0.004
1:25 PM	0.002	0.016		0.004	0.007
1:26 PM	0.002	0.022		0.003	0.005
1:27 PM	0.004	0.026		0.004	0.002
1:28 PM	0.016	0.026		0.004	0.009
1:29 PM	0.003	0.011		0.005	0.005
1:30 PM	0.002	0.013		0.005	0.003
1:31 PM	0.002	0.029		0.005	0.003
1:32 PM	0.002	0.027		0.008	0.005
1:33 PM	0.002	0.016		0.005	0.004
1:34 PM	0.002	0.019		0.005	0.005
1:35 PM	0.002	0.013		0.007	0.002
1:36 PM	0.002	0.014		0.007	0.002
1:37 PM	0.002	0.014		0.007	0.002
1:38 PM	0.002	0.014		0.005	0.004
1:39 PM	0.002	0.007		0.005	0.005
1:40 PM	0.002	0.006		0.005	0.005
1:41 PM	0.013	0.011		0.004	0.006
1:42 PM	0.021	0.014		0.005	0.005
1:43 PM	0.034	0.021		0.006	0.004

Time	Site 1	Site 2	Site 3	Site 4	Site 5
1:44 PM	0.038	0.014		0.005	0.003
1:45 PM	0.042	0.025		0.007	0.009
1:46 PM	0.038	0.021		0.006	0.010
1:47 PM	0.038	0.018		0.006	0.009
1:48 PM	0.034	0.015		0.006	0.013
1:49 PM	0.036	0.018		0.008	0.015
1:50 PM	0.027	0.015		0.010	0.013
1:51 PM	0.021	0.023		0.010	0.010
1:52 PM	0.015	0.027		0.012	0.009
1:53 PM	0.020	0.020		0.017	0.007
1:54 PM	0.019	0.013		0.013	0.006
1:55 PM	0.010	0.013		0.019	0.005
1:56 PM	0.005	0.024		0.004	0.005
1:57 PM	0.003	0.025		0.003	0.009
1:58 PM	0.010	0.026		0.003	0.011
1:59 PM	0.009	0.026		0.006	0.008
2:00 PM	0.025	0.030		0.007	0.009
2:01 PM	0.037	0.030		0.008	0.010
2:02 PM	0.045	0.031		0.007	0.010
2:03 PM	0.035	0.030		0.007	0.011
2:04 PM	0.015	0.036		0.013	0.011
2:05 PM	0.003	0.016		0.019	0.015
2:06 PM	0.003	0.022		0.032	0.006
2:07 PM	0.002	0.024		[illegible]	0.006
2:08 PM	0.003	0.025		0.036	0.009
2:09 PM	0.002	0.019		0.031	0.009
2:10 PM	0.002	0.020		0.020	0.010
2:11 PM	0.004	0.016		0.016	0.009
2:12 PM	0.011	0.011		0.014	0.005
2:13 PM	0.020	0.012		0.018	0.004
2:14 PM	0.012	0.013		0.018	0.002
2:15 PM	0.013	0.019		0.025	0.002
2:16 PM	0.020	0.019	0.009	0.040	0.003
2:17 PM	0.005	0.013	0.002	0.051	0.002
2:18 PM	0.002	0.010	0.002	0.049	0.003
2:19 PM	0.004	0.027	0.002	0.040	0.004
2:20 PM	0.006	0.024	0.002	0.033	0.005
2:21 PM	0.007	0.022	0.002	0.031	0.009
2:22 PM	0.005	0.020	0.002	0.030	0.006
2:23 PM	0.002	0.022	0.002	0.026	0.006
2:24 PM	0.002	0.019	0.002	0.021	0.008
2:25 PM	0.002	0.019	0.002	0.014	0.012
2:26 PM	0.002	0.013	0.002	0.017	0.014
2:27 PM	0.002	0.013	0.002	0.018	0.008
2:28 PM	0.002	0.014	0.002	0.014	0.007
2:29 PM	0.002	0.017	0.002	0.014	0.007

Time	Site 1	Site 2	Site 3	Site 4	Site 5
2:30 PM	0.004	0.016	0.002	0.009	0.011
2:31 PM	0.004	0.012	0.002	0.002	0.008
2:32 PM	0.002	0.007	0.002	0.002	0.009
2:33 PM	0.003	0.002	0.002	0.002	0.009
2:34 PM	0.006	0.002	0.002	0.002	0.008
2:35 PM	0.032	0.007	0.002	0.002	0.013
2:36 PM	0.020	0.003	0.002	0.002	0.011
2:37 PM	0.011	0.006	0.002	0.002	0.010
2:38 PM	0.005	0.003	0.002	0.002	0.010
2:39 PM	0.006	0.003	0.002	0.002	0.006
2:40 PM		0.002	0.002	0.011	0.005
2:41 PM		0.002	0.002	0.012	0.007
2:42 PM		0.002	0.002	0.010	0.007
2:43 PM		0.002	0.002	0.007	0.005
2:44 PM		0.002	0.002	0.004	0.003
2:45 PM		0.002	0.002	0.003	0.007
2:46 PM		0.002	0.002	0.002	0.003
2:47 PM		0.002	0.002	0.002	0.004
2:48 PM		0.002	0.002	0.003	0.003
2:49 PM		0.002	0.003	0.004	0.004
2:50 PM		0.002	0.002	0.006	0.005
2:51 PM		0.002	0.002	0.005	0.003
2:52 PM		0.002	0.002	0.005	0.004
2:53 PM		0.002	0.002	0.009	0.004
2:54 PM		0.002	0.002	0.009	0.006
2:55 PM		0.002	0.002	0.009	0.008
2:56 PM		0.002	0.002	0.009	0.010
2:57 PM		0.002	0.002	0.011	0.013
2:58 PM		0.002	0.002	0.012	0.018
2:59 PM		0.002	0.002	0.013	0.021
3:00 PM		0.002	0.002	0.013	0.027
3:01 PM		0.003	0.002	0.013	0.028
3:02 PM		0.002	0.002	0.014	0.018
3:03 PM		0.002	0.002	0.015	0.011
3:04 PM		0.002	0.002	0.095	0.025
3:05 PM		0.005	0.002	0.013	0.002
3:06 PM		0.004	0.002	0.012	0.013
3:07 PM		0.003	0.002	0.012	0.018
3:08 PM		0.004	0.002	0.011	0.016
3:09 PM		0.004	0.002	0.011	0.021
3:10 PM		0.009	0.002	0.005	0.026
3:11 PM		0.005	0.002	0.002	
3:12 PM		0.014	0.002	0.004	
3:13 PM		0.009	0.002	0.002	0.023
3:14 PM		0.011	0.002	0.003	0.026
3:15 PM		0.009	0.002	0.003	0.025

Time	Site 1	Site 2	Site 3	Site 4	Site 5
3:16 PM		0.004	0.002	0.005	0.023
3:17 PM		0.003	0.002	0.005	0.023
3:18 PM		0.003	0.004	0.006	0.029
3:19 PM		0.003	0.008	0.006	0.030
3:20 PM		0.002	0.018	0.009	0.032
3:21 PM		0.005	0.020	0.011	0.023
3:22 PM		0.010	0.007	0.010	0.020
3:23 PM		0.007	0.003	0.010	0.020
3:24 PM		0.005	0.004	0.014	0.026
3:25 PM		0.008	0.005	0.011	0.033
3:26 PM		0.013	0.003	0.012	0.036
3:27 PM		0.008	0.002	0.009	0.038
3:28 PM		0.008	0.002	0.008	0.040
3:29 PM		0.003	0.002	0.009	0.040
3:30 PM		0.002	0.002	0.009	0.034
3:31 PM		0.002	0.002	0.011	0.027
3:32 PM		0.002	0.002	0.006	0.026
3:33 PM		0.002	0.002	0.006	0.033
3:34 PM	0.010	0.002	0.002	0.006	0.036
3:35 PM	0.012	0.011	0.002	0.005	0.037
3:36 PM	0.014	0.012	0.002	0.008	0.011
3:37 PM	0.011	0.017	0.002	0.012	0.011
3:38 PM	0.002	0.011	0.002	0.020	0.014
3:39 PM	0.002	0.012	0.002	0.027	0.018
3:40 PM	0.002	0.011	0.002	0.012	0.021
3:41 PM	0.002	0.009	0.002	0.008	0.022
3:42 PM	0.002	0.006	0.002	0.008	0.023
3:43 PM	0.002	0.003	0.002	0.011	0.022
3:44 PM	0.002	0.005	0.002	0.013	0.024
3:45 PM	0.002	0.003	0.002	0.016	0.023
3:46 PM	0.002	0.004	0.002	0.022	0.024
3:47 PM	0.002	0.003	0.004	0.026	0.026
3:48 PM	0.003	0.002	0.003	0.027	0.025
3:49 PM	0.007	0.005	0.005	0.021	0.022
3:50 PM	0.006	0.005	0.006	0.021	0.026
3:51 PM	0.004	0.011	0.008	0.017	0.026
3:52 PM	0.005	0.016	0.002	0.024	0.027
3:53 PM	0.006	0.024	0.002	0.023	0.027
3:54 PM	0.007	0.016	0.002	0.021	0.025
3:55 PM	0.004	0.011	0.002	0.019	0.025
3:56 PM	0.004	0.004	0.002	0.016	0.021
3:57 PM	0.009	0.004	0.002	0.018	0.021
3:58 PM	0.016	0.022	0.002	0.018	0.025
3:59 PM	0.019	0.024	0.002	0.022	0.023
4:00 PM	0.034	0.015	0.002	0.019	0.025
4:01 PM	0.037	0.013	0.002	0.027	0.025

Time	Site 1	Site 2	Site 3	Site 4	Site 5
4:02 PM	0.037	0.023	0.002	0.023	0.028
4:03 PM	0.039	0.050	0.002	0.026	0.030
4:04 PM	0.003	0.078	0.002		0.031
4:05 PM	0.002				0.027
4:06 PM	0.002				0.017
4:07 PM	0.002				0.019
4:08 PM	0.002				
4:09 PM	0.002				
AVG	**0.010**	**0.014**	**0.004**	**0.009**	**0.010**
Max	**0.065**	**0.097**	**0.034**	**0.095**	**0.040**
Min	**0.002**	**0.001**	**0.001**	**0.002**	**0.001**

Annex IV

CO readings from Air Quality Monitor

CO Readings from Air Quality Monitor

Time	CO (ppm)				
	Site 1	Site 2	Site 3	Site 4	Site 5
9:22 AM		0.09			
9:24 AM		0.00			
9:26 AM		0.00			
9:28 AM		0.00			
9:30 AM		0.00	0.00		
9:32 AM		0.00	0.00		
9:34 AM		0.00	0.00		
9:36 AM		0.00	0.00		
9:38 AM		0.00	0.00		
9:40 AM		0.00	0.00		
9:42 AM	0.00	0.00	0.00		0.00
9:44 AM	0.00	0.00	0.00		0.00
9:46 AM	0.00	0.00	0.00		0.00
9:48 AM	0.00	0.00	0.00		0.00
9:50 AM	0.00	0.00	0.00		0.00
9:52 AM	0.00	0.00	0.00		0.00
9:54 AM	0.00	0.05	0.00		0.00
9:56 AM	0.00	0.00	0.00		0.00
9:58 AM	0.00	0.47	0.00		0.00
10:00 AM	0.00	0.35	0.00		0.00
10:02 AM	0.00	0.21	0.00		0.00
10:04 AM	0.00	0.24	0.00		0.00
10:06 AM	0.00	0.09	0.00		0.00
10:08 AM	0.00	0.05	0.00		0.00
10:10 AM	0.00	0.10	0.00		0.00
10:12 AM	0.00	0.09	0.00	0.00	0.00
10:14 AM	0.00	0.01	0.00	0.00	0.00
10:16 AM	0.00	0.04	0.00	0.00	0.00
10:18 AM	0.00	0.16	0.00	0.00	0.00
10:20 AM	0.00	0.12	0.00	0.00	0.00
10:22 AM	0.00	0.26	0.00	0.00	0.00
10:24 AM	0.00	0.30	0.00	0.00	0.00
10:26 AM	0.00	0.44	0.00	0.00	0.00
10:28 AM	0.00	0.24	0.00	0.00	0.00
10:30 AM	0.00	0.05	0.00	0.00	0.00
10:32 AM	0.00	0.00	0.00	0.00	0.00
10:34 AM	0.00	0.07	0.00	0.00	0.00
10:36 AM	0.00	0.02	0.00	0.00	0.00
10:38 AM	0.00	0.00	0.00	0.00	0.00
10:40 AM	0.00	0.00	0.00	0.00	0.00
10:42 AM	0.00	0.17	0.00	0.00	0.00
10:44 AM	0.00	0.70	0.00	0.00	0.00

Time	CO (ppm)				
	Site 1	Site 2	Site 3	Site 4	Site 5
10:46 AM	0.00	0.37	0.00	0.00	0.00
10:48 AM	0.00	0.12	0.00	0.00	0.00
10:50 AM	0.00	0.36	0.00	0.00	0.00
10:52 AM	0.00	1.93	0.00	0.00	0.00
10:54 AM	0.00	0.77	0.00	0.00	0.00
10:56 AM	0.00	0.37	0.00	0.00	0.00
10:58 AM	0.00	0.28	0.00	0.00	0.00
11:00 AM	0.00	0.06	0.00	0.00	0.00
11:02 AM	0.00	0.27	0.00	0.00	0.00
11:04 AM	0.00	0.20	0.00	0.00	0.00
11:06 AM	0.00	0.00	0.00	0.00	0.00
11:08 AM	0.00	0.40	0.00	0.00	0.00
11:10 AM	0.00	0.53	0.00	0.00	0.00
11:12 AM	0.00	0.59	0.00	0.00	0.00
11:14 AM	0.00	0.24	0.00	0.00	0.00
11:16 AM	0.00	0.56	0.00	0.00	0.00
11:18 AM	0.00	0.71	0.00	0.00	0.00
11:20 AM	0.00	0.81	0.00	0.00	0.00
11:22 AM	0.00	0.89	0.00	0.00	0.00
11:24 AM	0.00	0.75	0.00	0.00	0.00
11:26 AM	0.00	0.77	0.00	0.00	0.00
11:28 AM	0.00	0.72	0.00	0.00	0.00
11:30 AM	0.00	0.79	0.00	0.00	0.00
11:32 AM	0.00	0.76	0.00	0.00	0.00
11:34 AM	0.00	0.88	0.00	0.00	0.00
11:36 AM	0.00	1.04	0.00	0.00	0.00
11:38 AM	0.06	1.10	0.00	0.00	0.00
11:40 AM	0.02	0.91	0.00	0.00	0.00
11:42 AM	0.00	0.86	0.00	0.00	0.00
11:44 AM	0.00	1.13	0.00	0.00	0.00
11:46 AM	0.00	1.11	0.00	0.00	0.00
11:48 AM	0.00	1.24	0.00	0.00	0.00
11:50 AM	0.00	1.33	0.00	0.00	0.00
11:52 AM	0.00	1.24	0.00	0.00	0.00
11:54 AM	0.00	1.11	0.00	0.00	0.00
11:56 AM	0.00	0.84	0.00	0.00	0.00
11:58 AM	0.00	0.89	0.00	0.00	0.00
12:00 PM	0.00	0.79	0.00	0.00	0.00
12:02 PM	0.00	0.79	0.00	0.00	0.00
12:04 PM	0.00	0.91	0.00	0.00	0.00
12:06 PM	0.00	1.11	0.00	0.00	0.00
12:08 PM	0.00	1.08	0.00	0.00	0.00
12:10 PM	0.00	1.19	0.00	0.00	0.00
12:12 PM	0.00	1.09	0.00	0.00	0.00

Time	CO (ppm)				
	Site 1	Site 2	Site 3	Site 4	Site 5
12:14 PM	0.00	1.02	0.00	0.00	0.00
12:16 PM	0.00	0.89	0.00	0.00	0.00
12:18 PM	0.00	0.91	0.00	0.00	0.00
12:20 PM	0.00	0.84	0.00	0.00	0.00
12:22 PM	0.00	0.63	0.00	0.00	0.00
12:24 PM	0.00	0.88	0.00	0.00	0.00
12:26 PM	0.00	0.98	0.00	0.00	0.00
12:28 PM	0.00	0.95	0.00	0.00	0.00
12:30 PM	0.00	0.96	0.00	0.00	0.00
12:32 PM	0.00	0.76	0.00	0.00	0.00
12:34 PM	0.00	0.82	0.00	0.00	0.00
12:36 PM	0.00	0.78	0.00	0.00	0.00
12:38 PM	0.00	0.73	0.00	0.00	0.00
12:40 PM	0.00	0.90	0.00	0.00	0.00
12:42 PM	0.00	1.13	0.00	0.00	0.00
12:44 PM	0.00	0.91	0.00	0.00	0.00
12:46 PM	0.00	0.70	0.00	0.00	0.00
12:48 PM	0.00	0.73	0.00	0.00	0.00
12:50 PM	0.00	0.82	0.00	0.00	0.00
12:52 PM	0.00	0.78	0.00	0.00	0.00
12:54 PM	0.00	0.63	0.00	0.00	0.00
12:56 PM	0.00	0.52	0.00	0.00	0.00
12:58 PM	0.00	0.38	0.00	0.00	0.00
1:00 PM	0.00	0.49	0.00	0.00	0.00
1:02 PM	0.00	0.49	0.00	0.00	0.00
1:04 PM	0.00	0.50	0.00	0.00	0.00
1:06 PM	0.00	0.35	0.00	0.00	0.00
1:08 PM	0.00	0.35	0.00	0.00	0.00
1:10 PM	0.00	0.33	0.00	0.00	0.00
1:12 PM	0.00	0.28	0.00	0.00	0.00
1:14 PM	0.00	0.34	0.00	0.00	0.00
1:16 PM	0.00	0.45	0.00	0.00	0.00
1:18 PM	0.00	0.38	0.00	0.00	0.00
1:20 PM	0.00	0.36	0.00	0.00	0.00
1:22 PM	0.00	0.81	0.00	0.00	0.00
1:24 PM	0.00	0.52	0.00	0.00	0.00
1:26 PM	0.00	0.37	0.00	0.00	0.00
1:28 PM	0.00	0.38	0.00	0.00	0.00
1:30 PM	0.00	0.43	0.00	0.00	0.00
1:32 PM	0.00	0.65	0.00	0.00	0.00
1:34 PM	0.00	0.66	0.00	0.00	0.00
1:36 PM	0.00	0.60	0.02	0.00	0.00
1:38 PM	0.00	0.52	0.00	0.00	0.00
1:40 PM	0.00	0.29	0.00	0.00	0.00

Time	CO (ppm)				
	Site 1	Site 2	Site 3	Site 4	Site 5
1:42 PM	0.00	0.34	0.00	0.00	0.00
1:44 PM	0.00	0.53	0.00	0.00	0.00
1:46 PM	0.00	0.42	0.00	0.00	0.00
1:48 PM	0.00	0.39	0.00	0.00	0.00
1:50 PM	0.00	0.49	0.00	0.00	0.00
1:52 PM	0.00	0.45	0.00	0.00	0.00
1:54 PM	0.00	0.53	0.00	0.00	0.00
1:56 PM	0.00	0.44	0.00	0.00	0.00
1:58 PM	0.00	0.39	0.00	0.00	0.00
2:00 PM	0.00	0.40	0.00	0.00	0.00
2:02 PM	0.00	0.22	0.00	0.00	0.00
2:04 PM	0.00	0.53	0.00	0.00	0.00
2:06 PM	0.00	0.73	0.00	0.00	0.00
2:08 PM	0.00	0.78	0.00	0.00	0.00
2:10 PM	0.00	0.67	0.00	0.00	0.00
2:12 PM	0.00	0.59	0.00	0.00	0.00
2:14 PM	0.00	0.38	0.00	0.00	0.00
2:16 PM	0.00	0.30	0.00	0.00	0.00
2:18 PM	0.00	0.41	0.00	0.00	0.00
2:20 PM	0.00	1.10	0.00	0.00	0.00
2:22 PM	0.00	0.90	0.00	0.00	0.00
2:24 PM	0.00	0.80	0.00	0.00	0.00
2:26 PM	0.00	0.61	0.00	0.00	0.00
2:28 PM	0.00	0.52	0.00	0.00	0.00
2:30 PM	0.00	0.29	0.00	0.00	0.00
2:32 PM	0.00	0.34	0.00	0.00	0.00
2:34 PM	0.00	0.36	0.00	0.00	0.00
2:36 PM	0.00	0.30	0.00	0.00	0.00
2:38 PM	0.00	0.25	0.00	0.00	0.00
2:40 PM	0.00	0.29	0.00	0.00	0.00
2:42 PM	0.00	0.59	0.00	0.00	0.00
2:44 PM	0.00	0.58	0.00	0.00	0.00
2:46 PM	0.00	0.19	0.00	0.00	0.00
2:48 PM	0.00	0.13	0.00	0.00	0.00
2:50 PM	0.00	0.05	0.00	0.00	0.00
2:52 PM	0.00	0.18	0.00	0.00	0.00
2:54 PM	0.00	0.30	0.00	0.00	0.00
2:56 PM	0.00	0.24	0.00	0.00	0.00
2:58 PM	0.00	0.45	0.00	0.00	0.00
3:00 PM	0.00	0.51	0.00	0.00	0.00
3:02 PM	0.00	0.28	0.00	0.00	0.00
3:04 PM	0.00	0.22	0.00	0.00	0.00
3:06 PM	0.00	0.21	0.00	0.00	0.00
3:08 PM	0.00	0.12	0.00	0.00	0.00

Time	CO (ppm)				
	Site 1	Site 2	Site 3	Site 4	Site 5
3:10 PM	0.00	0.04	0.00	0.00	0.00
3:12 PM	0.00	0.00	0.00	0.00	0.00
3:14 PM	0.00	0.00	0.00	0.00	0.00
3:16 PM	0.00	0.24	0.00	0.00	0.00
3:18 PM	0.00	0.05	0.00	0.00	0.00
3:20 PM	0.00	0.00	0.00	0.00	0.00
3:22 PM	0.00	0.00	0.00	0.00	0.00
3:24 PM	0.00	0.00	0.00	0.00	0.00
3:26 PM	0.00	0.00	0.00	0.00	0.00
3:28 PM	0.00	0.00	0.00	0.00	0.00
3:30 PM	0.00	0.00	0.00	0.00	0.00
3:32 PM	0.00	0.00	0.00	0.00	0.00
3:34 PM	0.00	0.47	0.00	0.00	0.00
3:36 PM	0.00	0.05	0.00	0.00	0.00
3:38 PM	0.00	0.00	0.00	0.00	0.00
3:40 PM	0.00	0.00	0.00	0.00	0.00
3:42 PM	0.00	0.00	0.00	0.00	0.00
3:44 PM	0.00	0.00	0.00	0.00	0.00
3:46 PM	0.00	0.00	0.00	0.00	0.00
3:48 PM	0.00	0.34	0.00	0.00	0.00
3:50 PM	0.00	0.13	0.00	0.00	0.00
3:52 PM	0.00	0.12	0.00	0.00	0.00
3:54 PM	0.00	0.09	0.00	0.00	0.00
3:56 PM	0.00	0.04	0.00	0.00	0.00
3:58 PM	0.00	0.03	0.00	0.00	0.00
4:00 PM	0.00	0.04	0.00	0.00	0.00
4:02 PM	0.00	0.04	0.00	0.00	0.00
4:04 PM	0.00	0.04	0.00	0.00	0.00
4:06 PM	0.00	0.01	0.00	0.00	0.00
4:08 PM	0.00	0.16	0.00	0.00	0.00
4:10 PM	0.00	0.33	0.00	0.00	0.00
4:12 PM	0.00	0.38	0.00	0.00	0.00
4:14 PM	0.00	0.34	0.00	0.00	0.00
4:16 PM	0.00	0.25		0.00	0.00
4:18 PM	0.00	0.31		0.00	0.00
4:20 PM	0.00	0.27		0.00	0.00
4:22 PM	0.00	0.45		0.00	0.00
4:24 PM	0.00	0.34		0.00	0.00
4:26 PM	0.00	0.35			0.00
AVG	**0.00**	**0.42**	**0.00**	**0.00**	**0.00**

Annex V

Readings of Indoor & Outdoor temperatures and variation of temperature differences with time

Readings of Indoor and Outdoor temperatures and variation of temperature differences with time

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)
9:22:24				28.76											
9:24:24				28.74											
9:26:24				28.75											
9:28:24				28.71											
9:30:24		28.00		28.64	27.00	1.64	27.82	28.00	-0.18					29.00	
9:32:24		28.00		28.69	27.07	1.62	27.99	28.07	-0.08					29.11	
9:34:24		28.00		28.69	27.14	1.55	27.93	28.14	-0.21					29.21	
9:36:24		28.00		28.55	27.21	1.34	27.92	28.21	-0.29					29.32	
9:38:24		28.00		28.61	27.29	1.32	28.01	28.29	-0.28					29.43	
9:40:24		28.00		28.70	27.36	1.34	28.02	28.36	-0.34					29.54	
9:42:24	28.67	28.00	0.67	28.63	27.43	1.20	28.08	28.43	-0.35				29.93	29.64	0.29
9:44:24	28.73	28.00	0.73	28.64	27.50	1.14	28.19	28.50	-0.31				30.03	29.75	0.28
9:46:24	28.63	28.00	0.63	28.65	27.57	1.08	28.24	28.57	-0.33				30.16	29.86	0.30
9:48:24	28.51	28.00	0.51	28.75	27.64	1.11	28.16	28.64	-0.48				30.22	29.96	0.26
9:50:24	28.51	28.00	0.51	28.73	27.71	1.02	28.17	28.71	-0.54				30.29	30.07	0.22
9:52:24	28.42	28.00	0.42	28.85	27.79	1.06	28.25	28.79	-0.54				30.36	30.18	0.18
9:54:24	28.40	28.00	0.40	28.89	27.86	1.03	28.27	28.86	-0.59				30.38	30.29	0.09
9:56:24	28.31	28.00	0.31	28.85	27.93	0.92	28.23	28.93	-0.70				30.46	30.39	0.07
9:58:24	28.37	28.00	0.37	28.90	28.00	0.90	28.27	29.00	-0.73				30.55	30.50	0.05
10:00:24	28.39	28.00	0.39	28.86	28.00	0.86	28.34	29.00	-0.66		30.50		30.54	30.50	0.04
10:02:24	28.37	28.04	0.33	29.00	28.11	0.89	28.44	29.00	-0.56		30.54		30.66	30.54	0.12
10:04:24	28.41	28.07	0.34	29.01	28.21	0.80	28.44	29.00	-0.56		30.57		30.68	30.57	0.11

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor Temp (⁰C)	Outdoor Temp (⁰C)	Temp Difference (⁰C)	Indoor Temp (⁰C)	Outdoor Temp (⁰C)	Temp Difference (⁰C)	Indoor Temp (⁰C)	Outdoor Temp (⁰C)	Temp Difference (⁰C)	Indoor Temp (⁰C)	Outdoor Temp (⁰C)	Temp Difference (⁰C)	Indoor Temp (⁰C)	Outdoor Temp (⁰C)	Temp Difference (⁰C)
10:06:24	28.29	28.11	0.18	29.06	28.32	0.74	28.48	29.00	-0.52		30.61		30.76	30.61	0.15
10:08:24	28.38	28.14	0.24	29.17	28.43	0.74	28.50	29.00	-0.50		30.64		30.89	30.64	0.25
10:10:24	28.42	28.18	0.24	29.16	28.54	0.62	28.56	29.00	-0.44		30.68		30.86	30.68	0.18
10:12:24	28.44	28.21	0.23	29.11	28.64	0.47	28.60	29.00	-0.40	30.23	30.71	-0.48	30.96	30.71	0.25
10:14:24	28.30	28.25	0.05	29.14	28.75	0.39	28.63	29.00	-0.37	30.42	30.75	-0.33	31.10	30.75	0.35
10:16:24	28.38	28.29	0.09	29.16	28.86	0.30	28.57	29.00	-0.43	30.51	30.79	-0.28	31.12	30.79	0.33
10:18:24	28.39	28.32	0.07	29.21	28.96	0.25	28.54	29.00	-0.46	30.54	30.82	-0.28	31.17	30.82	0.35
10:20:24	28.36	28.36	0.00	29.27	29.07	0.20	28.51	29.00	-0.49	30.65	30.86	-0.21	31.06	30.86	0.20
10:22:24	28.39	28.39	0.00	29.19	29.18	0.01	28.64	29.00	-0.36	30.71	30.89	-0.18	31.17	30.89	0.28
10:24:24	28.43	28.43	0.00	29.19	29.29	-0.10	28.78	29.00	-0.22	30.68	30.93	-0.25	31.18	30.93	0.25
10:26:24	28.42	28.46	-0.04	29.32	29.39	-0.07	28.70	29.00	-0.30	30.75	30.96	-0.21	31.22	30.96	0.26
10:28:24	28.48	28.50	-0.02	29.33	29.50	-0.17	28.75	29.00	-0.25	30.86	31.00	-0.14	31.22	31.00	0.22
10:30:24	28.47	28.50	-0.03	29.34	29.50	-0.16	28.77	29.00	-0.23	30.99	31.00	-0.01	31.22	31.00	0.22
10:32:24	28.53	28.46	0.07	29.35	29.43	-0.08	28.83	29.07	-0.24	31.01	31.07	-0.06	31.18	31.00	0.18
10:34:24	28.48	28.43	0.05	29.31	29.36	-0.05	28.92	29.14	-0.22	31.03	31.14	-0.11	31.21	31.00	0.21
10:36:24	28.44	28.39	0.05	29.35	29.29	0.06	28.90	29.21	-0.31	31.13	31.21	-0.08	31.25	31.00	0.25
10:38:24	28.45	28.36	0.09	29.41	29.21	0.20	28.98	29.29	-0.31	31.18	31.29	-0.11	31.27	31.00	0.27
10:40:24	28.47	28.32	0.15	29.43	29.14	0.29	29.04	29.36	-0.32	31.18	31.36	-0.18	31.28	31.00	0.28
10:42:24	28.55	28.29	0.26	29.51	29.07	0.44	29.01	29.43	-0.42	31.36	31.43	-0.07	31.29	31.00	0.29
10:44:24	28.51	28.25	0.26	29.54	29.00	0.54	28.97	29.50	-0.53	31.44	31.50	-0.06	31.35	31.00	0.35
10:46:24	28.55	28.21	0.34	29.67	28.93	0.74	29.07	29.57	-0.50	31.55	31.57	-0.02	31.38	31.00	0.38
10:48:24	28.57	28.18	0.39	29.62	28.86	0.76	29.17	29.64	-0.47	31.58	31.64	-0.06	31.43	31.00	0.43
10:50:24	28.57	28.14	0.43	29.58	28.79	0.79	29.12	29.71	-0.59	31.67	31.71	-0.04	31.44	31.00	0.44
10:52:24	28.67	28.11	0.56	29.48	28.71	0.77	29.09	29.79	-0.70	31.65	31.79	-0.14	31.42	31.00	0.42
10:54:24	28.68	28.07	0.61	29.47	28.64	0.83	29.09	29.86	-0.77	31.66	31.86	-0.20	31.44	31.00	0.44

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor Temp (^0C)	Outdoor Temp (^0C)	Temp Difference (^0C)	Indoor Temp (^0C)	Outdoor Temp (^0C)	Temp Difference (^0C)	Indoor Temp (^0C)	Outdoor Temp (^0C)	Temp Difference (^0C)	Indoor Temp (^0C)	Outdoor Temp (^0C)	Temp Difference (^0C)	Indoor Temp (^0C)	Outdoor Temp (^0C)	Temp Difference (^0C)
10:56:24	28.60	28.04	0.56	29.41	28.57	0.84	29.13	29.93	-0.80	31.71	31.93	-0.22	31.50	31.00	0.50
10:58:24	28.60	28.00	0.60	29.51	28.50	1.01	29.19	30.00	-0.81	31.70	32.00	-0.30	31.48	31.00	0.48
11:00:24	28.64	28.00	0.64	29.46	28.50	0.96	29.23	30.00	-0.77	31.73	32.00	-0.27	31.44	31.00	0.44
11:02:24	28.62	28.04	0.58	29.51	28.46	1.05	29.21	30.00	-0.79	31.74	32.00	-0.26	31.42	31.04	0.38
11:04:24	28.52	28.07	0.45	29.60	28.43	1.17	29.23	30.00	-0.77	31.68	32.00	-0.32	31.39	31.07	0.32
11:06:24	28.60	28.11	0.49	29.50	28.39	1.11	29.28	30.00	-0.72	31.68	32.00	-0.32	31.44	31.11	0.33
11:08:24	28.59	28.14	0.45	30.43	28.36	2.07	29.34	30.00	-0.66	31.65	32.00	-0.35	31.43	31.14	0.29
11:10:24	28.62	28.18	0.44	29.69	28.32	1.37	29.34	30.00	-0.66	31.64	32.00	-0.36	31.53	31.18	0.35
11:12:24	28.58	28.21	0.37	29.62	28.29	1.33	29.32	30.00	-0.68	31.68	32.00	-0.32	31.48	31.21	0.27
11:14:24	28.62	28.25	0.37	29.57	28.25	1.32	29.34	30.00	-0.66	31.76	32.00	-0.24	31.60	31.25	0.35
11:16:24	28.55	28.29	0.26	29.52	28.21	1.31	29.37	30.00	-0.63	31.81	32.00	-0.19	31.54	31.29	0.25
11:18:24	28.64	28.32	0.32	29.50	28.18	1.32	29.36	30.00	-0.64	31.92	32.00	-0.08	31.52	31.32	0.20
11:20:24	28.61	28.36	0.25	29.47	28.14	1.33	29.41	30.00	-0.59	31.99	32.00	-0.01	31.59	31.36	0.23
11:22:24	28.55	28.39	0.16	29.42	28.11	1.31	29.44	30.00	-0.56	31.91	32.00	-0.09	31.61	31.39	0.22
11:24:24	28.46	28.43	0.03	29.47	28.07	1.40	29.46	30.00	-0.54	31.80	32.00	-0.20	31.62	31.43	0.19
11:26:24	28.54	28.46	0.08	29.51	28.04	1.47	29.50	30.00	-0.50	31.84	32.00	-0.16	31.67	31.46	0.21
11:28:24	28.52	28.50	0.02	29.49	28.00	1.49	29.52	30.00	-0.48	31.83	32.00	-0.17	31.66	31.50	0.16
11:30:24	28.50	28.50	0.00	29.40	28.00	1.40	29.55	30.00	-0.45	31.83	32.00	-0.17	31.58	31.50	0.08
11:32:24	28.48	28.46	0.02	29.47	28.04	1.43	29.65	30.04	-0.39	31.83	32.04	-0.21	31.58	31.57	0.01
11:34:24	28.57	28.43	0.14	29.44	28.07	1.37	29.62	30.07	-0.45	31.81	32.07	-0.26	31.61	31.64	-0.03
11:36:24	28.49	28.39	0.10	29.43	28.11	1.32	29.57	30.11	-0.54	31.74	32.11	-0.37	31.72	31.71	0.01
11:38:24	28.57	28.36	0.21	29.44	28.14	1.30	29.67	30.14	-0.47	31.84	32.14	-0.30	31.75	31.79	-0.04
11:40:24	28.57	28.32	0.25	29.41	28.18	1.23	29.67	30.18	-0.51	31.85	32.18	-0.33	31.74	31.86	-0.12
11:42:24	28.58	28.29	0.29	29.44	28.21	1.23	29.64	30.21	-0.57	31.88	32.21	-0.33	31.92	31.93	-0.01
11:44:24	28.54	28.25	0.29	29.39	28.25	1.14	29.58	30.25	-0.67	31.88	32.25	-0.37	32.03	32.00	0.03

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)
11:46:24	28.61	28.21	0.40	29.40	28.29	1.11	29.75	30.29	-0.54	31.87	32.29	-0.42	32.06	32.07	-0.01
11:48:24	28.57	28.18	0.39	29.44	28.32	1.12	29.82	30.32	-0.50	31.84	32.32	-0.48	32.07	32.14	-0.07
11:50:24	28.59	28.14	0.45	29.37	28.36	1.01	29.83	30.36	-0.53	31.83	32.36	-0.53	32.12	32.21	-0.09
11:52:24	28.63	28.11	0.52	29.44	28.39	1.05	29.98	30.39	-0.41	31.81	32.39	-0.58	32.03	32.29	-0.26
11:54:24	28.63	28.07	0.56	29.36	28.43	0.93	30.05	30.43	-0.38	31.85	32.43	-0.58	32.05	32.36	-0.31
11:56:24	28.68	28.04	0.64	29.35	28.46	0.89	30.04	30.46	-0.42	31.80	32.46	-0.66	32.07	32.43	-0.36
11:58:24	28.71	28.00	0.71	29.34	28.50	0.84	30.11	30.50	-0.39	31.78	32.50	-0.72	32.07	32.50	-0.43
12:00:24	28.71	28.00	0.71	29.40	28.50	0.90	30.09	30.50	-0.41	31.84	32.50	-0.66	32.14	32.50	-0.36
12:02:24	28.74	28.07	0.67	29.40	28.50	0.90	30.20	30.50	-0.30	31.92	32.54	-0.62	32.23	32.54	-0.31
12:04:24	28.69	28.14	0.55	29.36	28.50	0.86	30.32	30.50	-0.18	31.92	32.57	-0.65	32.26	32.57	-0.31
12:06:24	28.70	28.21	0.49	29.37	28.50	0.87	30.36	30.50	-0.14	31.96	32.61	-0.65	32.28	32.61	-0.33
12:08:24	28.61	28.29	0.32	29.33	28.50	0.83	30.31	30.50	-0.19	31.94	32.64	-0.70	32.34	32.64	-0.30
12:10:24	28.63	28.36	0.27	29.46	28.50	0.96	30.35	30.50	-0.15	32.07	32.68	-0.61	32.42	32.68	-0.26
12:12:24	28.71	28.43	0.28	29.40	28.50	0.90	30.34	30.50	-0.16	32.08	32.71	-0.63	32.43	32.71	-0.28
12:14:24	28.68	28.50	0.18	29.45	28.50	0.95	30.29	30.50	-0.21	32.06	32.75	-0.69	32.49	32.75	-0.26
12:16:24	28.66	28.57	0.09	29.35	28.50	0.85	30.30	30.50	-0.20	32.18	32.79	-0.61	32.58	32.79	-0.21
12:18:24	28.71	28.64	0.07	29.33	28.50	0.83	30.36	30.50	-0.14	32.22	32.82	-0.60	32.64	32.82	-0.18
12:20:24	28.66	28.71	-0.05	29.27	28.50	0.77	30.41	30.50	-0.09	32.22	32.86	-0.64	32.75	32.86	-0.11
12:22:24	28.69	28.79	-0.10	29.29	28.50	0.79	30.55	30.50	0.05	32.32	32.89	-0.57	32.68	32.89	-0.21
12:24:24	28.66	28.86	-0.20	29.21	28.50	0.71	30.52	30.50	0.02	32.35	32.93	-0.58	32.68	32.93	-0.25
12:26:24	28.69	28.93	-0.24	29.24	28.50	0.74	30.58	30.50	0.08	32.30	32.96	-0.66	32.78	32.96	-0.18
12:28:24	28.75	29.00	-0.25	29.31	28.50	0.81	30.59	30.50	0.09	32.30	33.00	-0.70	32.75	33.00	-0.25
12:30:24	28.77	29.00	-0.23	29.35	28.50	0.85	30.72	30.50	0.22	32.37	33.00	-0.63	32.68	33.00	-0.32
12:32:24	28.86	28.96	-0.10	29.26	28.50	0.76	30.94	30.46	0.48	32.39	33.00	-0.61	32.77	33.04	-0.27
12:34:24	28.93	28.93	0.00	29.25	28.50	0.75	30.87	30.43	0.44	32.30	33.00	-0.70	32.88	33.07	-0.19

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)
12:36:24	28.91	28.89	0.02	29.26	28.50	0.76	30.83	30.39	0.44	32.45	33.00	-0.55	32.92	33.11	-0.19
12:38:24	28.93	28.86	0.07	29.32	28.50	0.82	30.88	30.36	0.52	32.48	33.00	-0.52	32.91	33.14	-0.23
12:40:24	28.98	28.82	0.16	29.33	28.50	0.83	30.90	30.32	0.58	32.53	33.00	-0.47	32.89	33.18	-0.29
12:42:24	29.01	28.79	0.22	29.38	28.50	0.88	30.98	30.29	0.69	32.50	33.00	-0.50	32.92	33.21	-0.29
12:44:24	28.85	28.75	0.10	29.27	28.50	0.77	31.02	30.25	0.77	32.61	33.00	-0.39	32.88	33.25	-0.37
12:46:24	28.92	28.71	0.21	29.33	28.50	0.83	30.98	30.21	0.77	32.67	33.00	-0.33	32.86	33.29	-0.43
12:48:24	28.91	28.68	0.23	29.36	28.50	0.86	31.05	30.18	0.87	32.64	33.00	-0.36	32.90	33.32	-0.42
12:50:24	28.94	28.64	0.30	29.44	28.50	0.94	30.92	30.14	0.78	32.67	33.00	-0.33	32.92	33.36	-0.44
12:52:24	28.90	28.61	0.29	29.34	28.50	0.84	30.79	30.11	0.68	32.64	33.00	-0.36	32.95	33.39	-0.44
12:54:24	28.85	28.57	0.28	29.38	28.50	0.88	30.69	30.07	0.62	32.67	33.00	-0.33	32.96	33.43	-0.47
12:56:24	28.99	28.54	0.45	29.36	28.50	0.86	30.71	30.04	0.67	32.81	33.00	-0.19	32.94	33.46	-0.52
12:58:24	28.98	28.50	0.48	29.39	28.50	0.89	30.61	30.00	0.61	32.74	33.00	-0.26	32.97	33.50	-0.53
13:00:24	29.02	28.50	0.52	29.33	28.50	0.83	30.55	30.00	0.55	32.68	33.00	-0.32	33.08	33.50	-0.42
13:02:24	28.96	28.54	0.42	29.33	28.50	0.83	30.42	29.93	0.49	32.72	33.00	-0.28	33.21	33.50	-0.29
13:04:24	28.92	28.57	0.35	29.39	28.50	0.89	30.34	29.86	0.48	32.74	33.00	-0.26	33.27	33.50	-0.23
13:06:24	29.00	28.61	0.39	29.34	28.50	0.84	30.26	29.79	0.47	32.79	33.00	-0.21	33.24	33.50	-0.26
13:08:24	29.01	28.64	0.37	29.33	28.50	0.83	30.24	29.71	0.53	32.84	33.00	-0.16	33.29	33.50	-0.21
13:10:24	28.98	28.68	0.30	29.37	28.50	0.87	30.15	29.64	0.51	32.83	33.00	-0.17	33.31	33.50	-0.19
13:12:24	28.98	28.71	0.27	29.33	28.50	0.83	30.17	29.57	0.60	32.88	33.00	-0.12	33.24	33.50	-0.26
13:14:24	28.88	28.75	0.13	29.33	28.50	0.83	30.08	29.50	0.58	32.91	33.00	-0.09	33.33	33.50	-0.17
13:16:24	28.93	28.79	0.14	29.33	28.50	0.83	30.15	29.43	0.72	32.79	33.00	-0.21	33.23	33.50	-0.27
13:18:24	28.93	28.82	0.11	29.31	28.50	0.81	30.06	29.36	0.70	32.78	33.00	-0.22	33.31	33.50	-0.19
13:20:24	28.96	28.86	0.10	29.26	28.50	0.76	30.05	29.29	0.76	32.92	33.00	-0.08	33.27	33.50	-0.23
13:22:24	29.05	28.89	0.16	29.32	28.50	0.82	30.00	29.21	0.79	32.94	33.00	-0.06	33.30	33.50	-0.20
13:24:24	29.09	28.93	0.16	29.27	28.50	0.77	30.09	29.14	0.95	32.97	33.00	-0.03	33.21	33.50	-0.29

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)
13:26:24	29.11	28.96	0.15	29.38	28.50	0.88	29.93	29.07	0.86	33.00	33.00	0.00	33.13	33.50	-0.37
13:28:24	29.14	29.00	0.14	29.31	28.50	0.81	29.85	29.00	0.85	33.13	33.00	0.13	33.23	33.50	-0.27
13:30:24	29.20	29.00	0.20	29.24	28.50	0.74	29.70	29.00	0.70	33.09	33.00	0.09	33.19	33.50	-0.31
13:32:24	29.23	29.04	0.19	29.25	28.46	0.79	29.72	29.00	0.72	33.10	33.00	0.10	33.31	33.46	-0.15
13:34:24	29.21	29.07	0.14	29.27	28.43	0.84	29.73	29.00	0.73	33.18	33.00	0.18	33.28	33.43	-0.15
13:36:24	29.28	29.11	0.17	29.31	28.39	0.92	29.64	29.00	0.64	33.14	33.00	0.14	33.33	33.39	-0.06
13:38:24	29.21	29.14	0.07	29.23	28.36	0.87	29.52	29.00	0.52	33.09	33.00	0.09	33.32	33.36	-0.04
13:40:24	29.10	29.18	-0.08	29.26	28.32	0.94	29.65	29.00	0.65	33.13	33.00	0.13	33.15	33.32	-0.17
13:42:24	29.11	29.21	-0.10	29.26	28.29	0.97	29.71	29.00	0.71	33.03	33.00	0.03	33.07	33.29	-0.22
13:44:24	29.14	29.25	-0.11	29.25	28.25	1.00	29.62	29.00	0.62	33.04	33.00	0.04	33.05	33.25	-0.20
13:46:24	29.12	29.29	-0.17	29.23	28.21	1.02	29.60	29.00	0.60	33.10	33.00	0.10	33.09	33.21	-0.12
13:48:24	29.15	29.32	-0.17	29.25	28.18	1.07	29.65	29.00	0.65	32.99	33.00	-0.01	33.03	33.18	-0.15
13:50:24	29.11	29.36	-0.25	29.25	28.14	1.11	29.63	29.00	0.63	32.98	33.00	-0.02	33.02	33.14	-0.12
13:52:24	29.21	29.39	-0.18	29.25	28.11	1.14	29.67	29.00	0.67	32.94	33.00	-0.06	32.96	33.11	-0.15
13:54:24	29.28	29.43	-0.15	29.19	28.07	1.12	29.66	29.00	0.66	32.85	33.00	-0.15	33.02	33.07	-0.05
13:56:24	29.20	29.46	-0.26	29.21	28.04	1.17	29.56	29.00	0.56	32.92	33.00	-0.08	32.95	33.04	-0.09
13:58:24	29.23	29.50	-0.27	29.13	28.00	1.13	29.58	29.00	0.58	32.96	33.00	-0.04	33.10	33.00	0.10
14:00:24	29.30	29.50	-0.20	29.11	28.00	1.11	29.55	29.00	0.55	32.94	33.00	-0.06	33.13	33.00	0.13
14:02:24	29.24	29.46	-0.22	29.26	28.04	1.22	29.51	29.00	0.51	32.97	32.96	0.01	33.09	32.93	0.16
14:04:24	29.34	29.43	-0.09	29.21	28.07	1.14	29.54	29.00	0.54	32.98	32.93	0.05	33.13	32.86	0.27
14:06:24	29.31	29.39	-0.08	29.17	28.11	1.06	29.48	29.00	0.48	32.90	32.89	0.01	33.15	32.79	0.36
14:08:24	29.32	29.36	-0.04	29.16	28.14	1.02	29.55	29.00	0.55	32.93	32.86	0.07	33.11	32.71	0.40
14:10:24	29.31	29.32	-0.01	29.19	28.18	1.01	29.59	29.00	0.59	32.94	32.82	0.12	33.14	32.64	0.50
14:12:24	29.27	29.29	-0.02	29.23	28.21	1.02	29.49	29.00	0.49	32.87	32.79	0.08	33.04	32.57	0.47
14:14:24	29.23	29.25	-0.02	29.19	28.25	0.94	29.52	29.00	0.52	32.87	32.75	0.12	33.08	32.50	0.58

Annex - V

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)
14:16:24	29.17	29.21	-0.04	29.18	28.29	0.89	29.57	29.00	0.57	32.82	32.71	0.11	32.97	32.43	0.54
14:18:24	29.17	29.18	-0.01	29.26	28.32	0.94	29.52	29.00	0.52	32.75	32.68	0.07	32.97	32.36	0.61
14:20:24	29.15	29.14	0.01	29.18	28.36	0.82	29.62	29.00	0.62	32.69	32.64	0.05	32.99	32.29	0.70
14:22:24	29.22	29.11	0.11	29.25	28.39	0.86	29.55	29.00	0.55	32.64	32.61	0.03	33.20	32.21	0.99
14:24:24	29.21	29.07	0.14	29.19	28.43	0.76	29.58	29.00	0.58	32.61	32.57	0.04	33.06	32.14	0.92
14:26:24	29.22	29.04	0.18	29.25	28.46	0.79	29.59	29.00	0.59	32.64	32.54	0.10	33.07	32.07	1.00
14:28:24	29.13	29.00	0.13	29.27	28.50	0.77	29.59	29.00	0.59	32.72	32.50	0.22	33.03	32.00	1.03
14:30:24	29.11	29.00	0.11	29.22	28.50	0.72	29.50	29.00	0.50	32.79	32.50	0.29	33.08	32.00	1.08
14:32:24	29.14	29.00	0.14	29.19	28.50	0.69	29.53	29.00	0.53	32.74	32.46	0.28	33.00	32.07	0.93
14:34:24	29.24	29.00	0.24	29.29	28.50	0.79	29.43	29.00	0.43	32.86	32.43	0.43	33.05	32.14	0.91
14:36:24	29.28	29.00	0.28	29.26	28.50	0.76	29.50	29.00	0.50	32.82	32.39	0.43	32.94	32.21	0.73
14:38:24	29.32	29.00	0.32	29.29	28.50	0.79	29.46	29.00	0.46	32.79	32.36	0.43	32.90	32.29	0.61
14:40:24	29.31	29.00	0.31	29.23	28.50	0.73	29.42	29.00	0.42	32.86	32.32	0.54	32.88	32.36	0.52
14:42:24	29.31	29.00	0.31	29.28	28.50	0.78	29.48	29.00	0.48	32.93	32.29	0.64	32.81	32.43	0.38
14:44:24	29.31	29.00	0.31	29.36	28.50	0.86	29.42	29.00	0.42	33.00	32.25	0.75	32.88	32.50	0.38
14:46:24	29.30	29.00	0.30	29.27	28.50	0.77	29.45	29.00	0.45	33.04	32.21	0.83	32.92	32.57	0.35
14:48:24	29.33	29.00	0.33	29.42	28.50	0.92	29.48	29.00	0.48	33.12	32.18	0.94	33.04	32.64	0.40
14:50:24	29.33	29.00	0.33	29.44	28.50	0.94	29.47	29.00	0.47	33.17	32.14	1.03	32.97	32.71	0.26
14:52:24	29.30	29.00	0.30	29.33	28.50	0.83	29.51	29.00	0.51	33.27	32.11	1.16	33.06	32.79	0.27
14:54:24	29.32	29.00	0.32	29.30	28.50	0.80	29.48	29.00	0.48	33.17	32.07	1.10	33.06	32.86	0.20
14:56:24	29.26	29.00	0.26	29.33	28.50	0.83	29.54	29.00	0.54	33.07	32.04	1.03	33.06	32.93	0.13
14:58:24	29.26	29.00	0.26	29.40	28.50	0.90	29.58	29.00	0.58	33.06	32.00	1.06	33.16	33.00	0.16
15:00:24	29.20	29.00	0.20	29.32	28.50	0.82	29.59	29.00	0.59	32.95	32.00	0.95	33.11	33.00	0.11
15:02:24	29.24	28.96	0.28	29.36	28.54	0.82	29.63	29.00	0.63	32.96	31.96	1.00	33.08	32.93	0.15
15:04:24	29.29	28.93	0.36	29.38	28.57	0.81	29.62	29.00	0.62	32.95	31.93	1.02	33.15	32.86	0.29

Annex - V

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)
15:06:24	29.34	28.89	0.45	29.35	28.61	0.74	29.49	29.00	0.49	32.89	31.89	1.00	33.18	32.79	0.39
15:08:24	29.26	28.86	0.40	29.37	28.64	0.73	29.59	29.00	0.59	32.79	31.86	0.93	33.20	32.71	0.49
15:10:24	29.28	28.82	0.46	29.37	28.68	0.69	29.59	29.00	0.59	32.68	31.82	0.86	33.05	32.64	0.41
15:12:24	29.31	28.79	0.52	29.42	28.71	0.71	29.61	29.00	0.61	32.54	31.79	0.75	33.03	32.57	0.46
15:14:24	29.17	28.75	0.42	29.41	28.75	0.66	29.71	29.00	0.71	32.55	31.75	0.80	33.01	32.50	0.51
15:16:24	29.30	28.71	0.59	29.44	28.79	0.65	29.65	29.00	0.65	32.58	31.71	0.87	32.97	32.43	0.54
15:18:24	29.27	28.68	0.59	29.48	28.82	0.66	29.70	29.00	0.70	32.51	31.68	0.83	32.98	32.36	0.62
15:20:24	29.28	28.64	0.64	29.47	28.86	0.61	29.67	29.00	0.67	32.55	31.64	0.91	33.03	32.29	0.74
15:22:24	29.24	28.61	0.63	29.47	28.89	0.58	29.69	29.00	0.69	32.38	31.61	0.77	32.96	32.21	0.75
15:24:24	29.23	28.57	0.66	29.43	28.93	0.50	29.71	29.00	0.71	32.46	31.57	0.89	32.83	32.14	0.69
15:26:24	29.26	28.54	0.72	29.49	28.96	0.53	29.74	29.00	0.74	32.46	31.54	0.92	32.83	32.07	0.76
15:28:24	29.24	28.50	0.74	29.58	29.00	0.58	29.77	29.00	0.77	32.51	31.50	1.01	32.87	32.00	0.87
15:30:24	29.17	28.50	0.67	29.57	29.00	0.57	29.81	29.00	0.81	32.56	31.50	1.06	32.73	32.00	0.73
15:32:24	29.19	28.46	0.73	29.55	29.00	0.55	29.75	29.00	0.75	32.53	31.50	1.03	32.66	31.93	0.73
15:34:24	29.25	28.43	0.82	29.51	29.00	0.51	29.76	29.00	0.76	32.38	31.50	0.88	32.65	31.86	0.79
15:36:24	29.17	28.39	0.78	29.53	29.00	0.53	29.74	29.00	0.74	32.27	31.50	0.77	32.67	31.79	0.88
15:38:24	29.13	28.36	0.77	29.60	29.00	0.60	29.83	29.00	0.83	32.22	31.50	0.72	32.67	31.71	0.96
15:40:24	29.10	28.32	0.78	29.55	29.00	0.55	29.82	29.00	0.82	32.19	31.50	0.69	32.61	31.64	0.97
15:42:24	29.13	28.29	0.84	29.46	29.00	0.46	29.77	29.00	0.77	32.19	31.50	0.69	32.57	31.57	1.00
15:44:24	29.03	28.25	0.78	29.52	29.00	0.52	29.81	29.00	0.81	32.23	31.50	0.73	32.54	31.50	1.04
15:46:24	28.96	28.21	0.75	29.57	29.00	0.57	29.75	29.00	0.75	32.28	31.50	0.78	32.53	31.43	1.10
15:48:24	28.99	28.18	0.81	29.53	29.00	0.53	29.72	29.00	0.72	32.27	31.50	0.77	32.46	31.36	1.10
15:50:24	28.92	28.14	0.78	29.57	29.00	0.57	29.76	29.00	0.76	32.24	31.50	0.74	32.43	31.29	1.14
15:52:24	28.81	28.11	0.70	29.48	29.00	0.48	29.75	29.00	0.75	32.25	31.50	0.75	32.41	31.21	1.20
15:54:24	28.89	28.07	0.82	29.41	29.00	0.41	29.74	29.00	0.74	32.23	31.50	0.73	32.27	31.14	1.13

Time	Site 1			Site 2			Site 3			Site 4			Site 5		
	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)	Indoor Temp (^{0}C)	Outdoor Temp (^{0}C)	Temp Difference (^{0}C)
15:56:24	28.78	28.04	0.74	29.46	29.00	0.46	29.71	29.00	0.71	32.17	31.50	0.67	32.19	31.07	1.12
15:58:24	28.75	28.00	0.75	29.43	29.00	0.43	29.75	29.00	0.75	32.22	31.50	0.72	32.20	31.00	1.20
16:00:24	28.78	28.00	0.78	29.48	29.00	0.48	29.85	29.00	0.85	32.20	31.50	0.70	32.21	31.00	1.21
16:02:24	28.80			29.45			29.77			32.27			32.17		
16:04:24	28.82			29.34			29.78			32.32			32.09		
16:06:24	28.74			29.42			29.78			32.30			32.11		
16:08:24	28.73			29.39			29.59			32.29			32.07		
16:10:24	28.73			29.36			29.55			32.25			32.15		
16:12:24	28.67			29.40			29.65			32.30			32.03		
16:14:24	28.65			29.39			29.59			32.34			32.02		
16:16:24	28.73			29.46						32.24			32.03		
16:18:24	28.63			29.43						32.21			31.92		
16:20:24	28.62			29.42						32.23			31.84		
16:22:24	28.72			29.45						32.24			31.80		
16:24:24	28.64			29.47						32.21			31.76		
16:26:24	28.62			29.56									31.77		
17:26:24	28.59												31.67		
AVG	**28.86**	**28.57**		**29.31**	**28.46**		**29.57**	**29.42**		**32.30**	**32.20**		**32.30**	**32.03**	

Annex VI

Indoor Relative Humidity Readings from Air Quality Monitor

Indoor Relative Humidity Readings from Air Quality Monitor

Time	Relative Humidity (%)				
	Site 1	Site 2	Site 3	Site 4	Site 5
9:22:24		78.2			
9:24:24		78.0			
9:26:24		78.3			
9:28:24		78.5			
9:30:24		78.6	79.9		
9:32:24		78.6	79.8		
9:34:24		78.9	80.0		
9:36:24		79.1	80.3		
9:38:24		78.9	80.5		
9:40:24		78.8	80.7		
9:42:24	75.2	78.6	80.7		72.4
9:44:24	75.4	78.5	80.6		72.5
9:46:24	75.8	78.5	80.5		72.3
9:48:24	76.3	78.7	80.0		71.8
9:50:24	76.6	78.8	80.1		71.6
9:52:24	77.0	78.8	80.5		71.5
9:54:24	77.3	78.6	80.4		71.2
9:56:24	77.7	78.8	80.2		70.3
9:58:24	77.4	78.6	80.3		70.1
10:00:24	77.3	78.7	80.4		70.1
10:02:24	77.4	78.8	80.6		69.5
10:04:24	77.5	78.8	80.5		69.7
10:06:24	77.6	78.8	80.4		69.8
10:08:24	77.4	78.8	80.5		69.4
10:10:24	77.4	78.8	80.5		69.3
10:12:24	77.4	78.8	80.6	71.7	69.6
10:14:24	77.7	78.9	80.5	71.5	69.9
10:16:24	77.5	79.0	80.3	71.5	70.0
10:18:24	77.5	78.6	80.3	71.5	69.8
10:20:24	77.6	78.3	80.3	71.4	69.8
10:22:24	77.3	78.4	80.5	71.4	69.8
10:24:24	77.5	78.7	80.3	71.5	69.9
10:26:24	77.5	78.9	79.9	71.6	70.0
10:28:24	77.8	78.9	79.6	71.4	69.7
10:30:24	78.3	78.9	80.1	71.0	69.4
10:32:24	78.3	78.8	80.1	70.7	69.3

Time	Relative Humidity (%)				
	Site 1	Site 2	Site 3	Site 4	Site 5
10:34:24	78.6	78.7	80.1	70.9	69.5
10:36:24	78.2	78.8	80.3	70.9	69.6
10:38:24	78.0	78.8	80.2	70.9	69.5
10:40:24	78.1	78.6	80.0	70.9	69.4
10:42:24	78.3	78.5	80.0	70.7	69.4
10:44:24	77.8	78.6	80.0	70.6	69.4
10:46:24	77.9	78.1	80.0	70.7	68.9
10:48:24	78.2	78.1	80.0	70.4	68.6
10:50:24	77.7	78.1	79.4	70.2	68.8
10:52:24	77.4	78.3	79.3	69.8	68.7
10:54:24	77.5	78.2	79.6	70.0	68.9
10:56:24	77.7	78.3	79.6	70.0	69.1
10:58:24	77.6	78.1	79.6	70.0	68.6
11:00:24	77.5	78.2	79.7	70.1	68.5
11:02:24	77.6	78.1	79.8	69.9	68.4
11:04:24	77.8	78.0	79.8	69.8	68.8
11:06:24	78.3	78.0	79.4	69.4	69.0
11:08:24	78.3	76.5	79.3	69.5	69.4
11:10:24	78.3	77.9	79.1	69.7	69.4
11:12:24	78.2	78.0	79.0	70.0	69.2
11:14:24	78.0	77.8	78.9	70.3	69.1
11:16:24	77.8	77.8	78.9	69.8	69.0
11:18:24	77.8	78.0	78.9	69.9	69.1
11:20:24	77.9	78.0	78.9	70.0	68.8
11:22:24	77.7	77.9	78.9	70.0	68.8
11:24:24	77.7	77.9	78.9	69.8	68.8
11:26:24	77.7	77.8	78.4	69.8	68.7
11:28:24	78.0	77.9	78.6	69.8	68.8
11:30:24	77.7	77.9	78.7	69.6	68.9
11:32:24	78.0	77.9	78.5	69.6	69.0
11:34:24	78.1	78.0	78.4	69.7	68.9
11:36:24	78.1	77.6	78.2	69.8	68.9
11:38:24	78.2	77.6	78.3	70.1	68.9
11:40:24	78.1	77.8	78.0	70.3	69.0
11:42:24	78.1	77.8	77.7	70.2	69.0
11:44:24	78.3	78.0	77.9	70.0	68.6
11:46:24	78.7	77.9	77.9	69.6	68.2
11:48:24	78.5	77.8	77.0	69.5	67.9
11:50:24	78.5	77.9	77.0	69.6	68.1
11:52:24	78.2	78.0	77.3	69.5	68.5

Time	Relative Humidity (%)				
	Site 1	Site 2	Site 3	Site 4	Site 5
11:54:24	78.0	77.8	76.9	69.7	68.8
11:56:24	77.8	77.9	76.7	69.9	69.0
11:58:24	77.8	77.8	76.2	69.9	69.0
12:00:24	78.2	77.6	76.4	70.0	68.9
12:02:24	78.3	77.7	76.6	70.0	68.5
12:04:24	78.2	77.6	76.3	69.8	67.9
12:06:24	78.2	77.5	76.0	69.6	67.9
12:08:24	78.1	77.6	76.0	69.8	67.9
12:10:24	78.1	77.6	75.8	70.0	67.9
12:12:24	78.3	77.7	75.4	70.0	67.7
12:14:24	78.2	77.6	75.3	69.9	67.2
12:16:24	78.2	77.8	75.7	69.6	67.3
12:18:24	78.0	77.8	75.9	69.3	67.3
12:20:24	78.1	77.6	76.1	69.1	67.2
12:22:24	78.2	77.7	76.1	69.0	67.2
12:24:24	78.3	77.9	75.5	68.9	67.5
12:26:24	78.2	77.9	75.2	69.0	67.1
12:28:24	78.3	77.9	75.1	69.2	66.3
12:30:24	78.3	78.1	75.5	69.1	65.6
12:32:24	78.4	77.8	75.1	68.7	65.9
12:34:24	78.3	77.9	73.8	68.6	65.6
12:36:24	78.5	78.2	73.7	68.5	65.1
12:38:24	78.5	78.2	74.5	68.7	64.9
12:40:24	78.3	78.1	74.0	68.7	64.9
12:42:24	78.2	78.2	74.1	68.7	64.3
12:44:24	78.1	78.2	74.4	68.6	64.2
12:46:24	78.0	78.1	74.8	68.4	63.9
12:48:24	77.8	78.2	74.8	68.3	64.2
12:50:24	77.8	78.3	74.2	68.3	64.2
12:52:24	78.1	78.2	74.3	68.3	64.3
12:54:24	78.1	78.0	74.3	68.3	64.1
12:56:24	78.4	78.2	74.6	68.2	63.6
12:58:24	78.3	78.4	74.3	68.4	64.1
13:00:24	78.4	78.6	74.1	68.6	64.0
13:02:24	78.3	78.6	73.9	68.3	63.9
13:04:24	77.8	78.4	74.2	68.6	63.5
13:06:24	77.7	78.3	74.1	68.6	63.8
13:08:24	77.4	78.2	73.9	68.4	63.8
13:10:24	77.4	78.4	74.3	68.4	63.7
13:12:24	77.6	78.3	74.6	68.4	64.0

Time	Relative Humidity (%)				
	Site 1	Site 2	Site 3	Site 4	Site 5
13:14:24	77.8	78.2	74.9	68.2	64.2
13:16:24	77.8	78.0	75.3	68.3	63.9
13:18:24	78.1	77.6	75.5	68.2	64.0
13:20:24	78.2	77.8	75.0	68.0	63.8
13:22:24	78.2	77.8	74.8	68.0	63.5
13:24:24	78.1	78.0	74.5	68.0	63.5
13:26:24	78.1	78.1	74.6	67.8	63.7
13:28:24	78.4	78.0	74.8	67.6	63.8
13:30:24	77.9	78.0	76.1	67.5	64.1
13:32:24	77.4	78.0	76.1	67.4	64.5
13:34:24	77.5	78.0	76.4	67.3	64.4
13:36:24	77.7	78.1	76.4	67.3	64.1
13:38:24	77.7	78.2	76.3	67.4	64.3
13:40:24	78.1	78.4	76.4	67.2	64.2
13:42:24	77.9	78.4	76.5	67.3	63.6
13:44:24	77.7	78.3	76.7	67.6	63.9
13:46:24	77.5	78.3	77.0	67.5	63.8
13:48:24	77.9	78.2	76.8	66.9	63.7
13:50:24	77.8	78.0	76.8	66.9	63.6
13:52:24	77.6	78.1	77.0	67.0	63.9
13:54:24	77.5	78.1	76.9	67.0	64.0
13:56:24	77.4	78.2	76.8	67.1	63.9
13:58:24	77.2	78.2	76.7	67.1	63.6
14:00:24	77.1	78.1	76.9	67.1	63.6
14:02:24	77.4	78.3	76.9	67.1	63.8
14:04:24	77.7	78.3	76.9	67.2	63.6
14:06:24	77.8	78.5	76.9	67.4	63.9
14:08:24	77.7	78.4	76.9	67.7	64.0
14:10:24	77.7	78.5	77.1	67.5	64.1
14:12:24	77.5	78.6	77.4	67.6	64.1
14:14:24	77.6	78.6	77.4	67.7	64.0
14:16:24	77.5	78.6	77.2	67.9	64.0
14:18:24	77.6	78.7	77.5	67.4	64.2
14:20:24	77.8	78.7	77.6	67.2	64.3
14:22:24	78.2	78.7	77.6	67.5	64.3
14:24:24	77.9	78.7	77.7	67.7	64.4
14:26:24	77.4	78.7	77.8	67.6	64.5
14:28:24	77.5	78.8	77.5	67.5	64.5
14:30:24	77.4	78.9	77.4	67.5	64.5
14:32:24	77.4	79.0	77.4	67.7	64.6

Time	Relative Humidity (%)				
	Site 1	Site 2	Site 3	Site 4	Site 5
14:34:24	77.5	78.9	77.6	67.6	64.0
14:36:24	77.4	78.9	77.5	67.4	63.8
14:38:24	77.0	78.9	77.5	67.3	64.0
14:40:24	77.1	79.0	77.5	67.4	64.2
14:42:24	77.1	78.9	77.7	67.5	64.4
14:44:24	76.9	78.9	77.9	67.4	64.4
14:46:24	76.7	79.0	77.9	67.2	64.8
14:48:24	76.9	78.9	77.7	67.1	64.6
14:50:24	77.1	78.9	77.5	67.3	64.6
14:52:24	77.1	78.8	77.6	67.3	64.6
14:54:24	77.2	78.7	77.5	66.7	64.6
14:56:24	77.5	78.6	77.6	66.3	64.5
14:58:24	77.4	78.3	77.6	66.5	64.5
15:00:24	77.4	78.2	77.7	66.9	64.2
15:02:24	77.5	78.2	77.6	67.2	64.0
15:04:24	77.7	78.3	77.6	67.2	64.0
15:06:24	77.7	78.3	77.5	66.7	63.5
15:08:24	77.4	78.3	77.5	66.4	63.6
15:10:24	77.1	78.3	77.6	66.5	63.8
15:12:24	77.1	78.3	77.7	67.0	64.0
15:14:24	77.6	78.3	77.7	67.0	64.0
15:16:24	77.7	78.3	77.8	67.3	64.3
15:18:24	77.6	78.4	77.6	67.5	64.6
15:20:24	77.6	78.4	77.7	67.7	64.9
15:22:24	77.6	78.3	77.6	67.8	64.7
15:24:24	77.7	78.3	77.8	67.8	64.2
15:26:24	77.7	78.1	77.7	67.8	64.0
15:28:24	77.7	78.1	77.7	67.6	64.3
15:30:24	77.9	78.1	77.7	67.4	64.9
15:32:24	78.0	78.2	78.1	67.3	65.4
15:34:24	77.8	78.3	78.0	67.3	65.4
15:36:24	77.8	78.3	78.0	67.3	65.4
15:38:24	77.8	78.1	77.9	67.2	65.5
15:40:24	77.3	78.1	77.8	67.5	65.6
15:42:24	77.2	78.4	77.7	67.8	65.2
15:44:24	77.4	78.2	77.7	67.9	65.1
15:46:24	77.3	78.2	77.6	67.9	65.7
15:48:24	77.5	78.2	77.7	67.9	66.1
15:50:24	78.0	78.0	77.7	67.7	66.3
15:52:24	78.1	77.8	77.6	67.6	65.9

Time	Relative Humidity (%)				
	Site 1	Site 2	Site 3	Site 4	Site 5
15:54:24	78.2	77.9	77.6	67.4	66.2
15:56:24	78.6	78.0	77.8	67.4	66.7
15:58:24	78.2	78.0	77.6	67.6	67.1
16:00:24	77.8	78.0	77.6	67.9	67.2
16:02:24	78.0	77.9	77.8	68.0	67.4
16:04:24	78.1	77.9	77.7	68.0	67.6
16:06:24	78.2	77.9	77.6	68.2	67.6
16:08:24	78.3	77.8	77.5	68.3	67.6
16:10:24	78.5	78.0	77.5	68.4	67.6
16:12:24	78.6	78.0	77.3	68.3	67.6
16:14:24	78.6	78.1	77.5	68.0	67.6
16:16:24	78.5	77.9		67.8	67.4
16:18:24	78.8	78.0		67.8	67.3
16:20:24	79.1	78.0		67.9	67.3
16:22:24	79.3	78.1		67.9	67.1
16:24:24	79.2	78.4		67.8	67.2
16:26:24	78.9	78.4			67.3
17:26:24	79.0				67.6
AVG	**77.8**	**78.3**	**77.6**	**68.6**	**66.6**

Annex VII

Measurements of Outdoor and Indoor wind speeds

Measurements of Indoor and Outdoor Wind Speed

Time (hh:mm)	Site 1		Site 2		Site 3		Site 4		Site 5	
	Indoor Wind Speed (m/2min)	Outdoor Wind Speed (m/2min)	Indoor Wind Speed (m/2min)	Outdoor Wind Speed (m/2min)	Indoor Wind Speed (m/2min)	Outdoor Wind Speed (m/2min)	Indoor Wind Speed (m/2min)	Outdoor Wind Speed (m/2min)	Indoor Wind Speed (m/2min)	Outdoor Wind Speed (m/2min)
9:30	34	6	5	24	0	14			3	39
10:00	14	34	8	16	9	50	0	8	2	12
10:30	16	19	6	16	20	84	1	6	0	26
11:00	12	26	4	33	22	59	0	20	5	22
11:30	18	12	2	14	5	118	5	8	5	35
12:00	13	10	3	32	5	110	20	38	9	33
12:30	26	82	5	10	4	105	8	9	5	22
13:00	32	55	3	42	6	90	18	24	5	47
13:30	20	43	4	34	13	100	8	14	9	63
14:00	17	13	5	33	7	43	8	16	10	33
14:30	18	74	2	32	3	38	9	10	5	25
15:00	24	35	7	10	1	10	28	20	20	27
15:30	3	9	15	12	3	14	3	2	28	13
16:00	10	39	0	18	3	20	8	8	15	15
Average Wind Speed (m/s)	**0.153**	**0.272**	**0.041**	**0.194**	**0.060**	**0.509**	**0.149**	**0.235**	**0.144**	**0.490**

Annex VIII

Questionnaire Survey

QUESTIONNAIRE SURVEY FOR INDOOR AIR QUALITY

1. GENERAL DETAILS

a) Sample Number : …………………………

b) Date : …………………………………

c) Time :

From ……………………… To ………………………

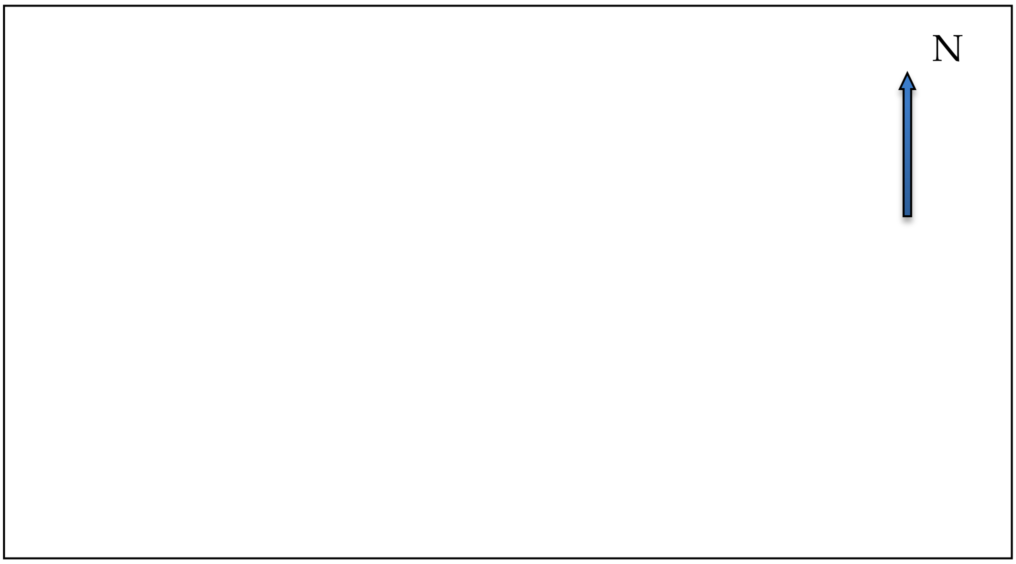
d) Number of occupants in the house:

Adults ………….. Children …………..

2. LOCATION MAP

3. DETAILS OF THE SITE AND BUILDING

e) Site Map (with location of Kitchen & Garage)



f) Plot Size ………………….perches

g) Plot Coverage by the Building …………………m^2

h) Percentage of plot coverage ………………%

i) Area covered by trees above 2m height ………………%

j) Area covered by shrubs ………………%

k) Area covered by paving slabs or concrete roads ………………%

4. DETAILS OF THE KITCHEN

a) Type of the Kitchen fuel use:

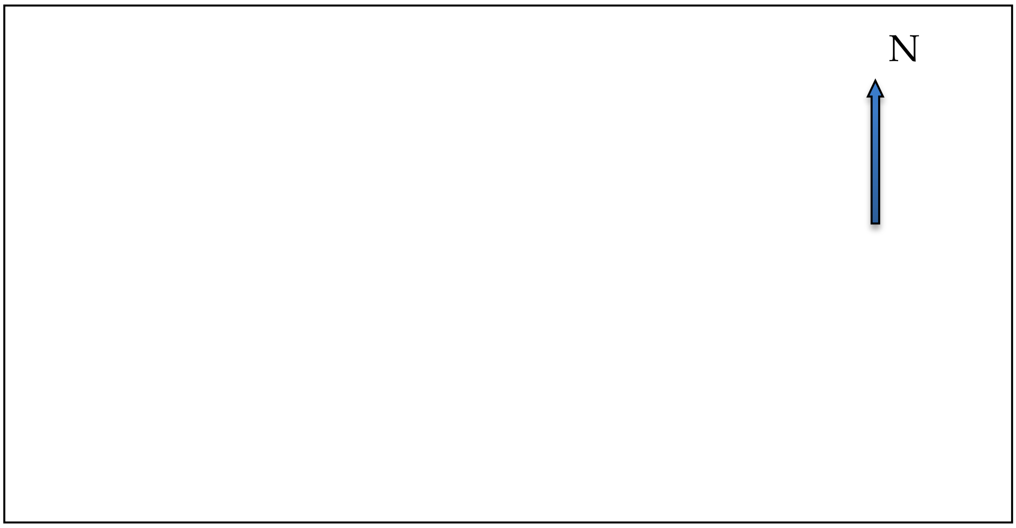
Hearth	[ ]	Gas Cooker	[ ]
Electric Cooker	[ ]	Kerosene Cooker	[ ]
Other (Specify)	[ ]		

……………………………………..

b) Whether a Chimney is present:

Yes [ ] No [ ]

c) Sketch of the kitchen with Chimney location



5. BUILDING CHARACTERISTICS

a) Type of the building:

Single story building [ ] Multi Story building [ ]

b) When was the building last colour washed or polished:

Recently [ ] 1 year ago [ ]

2 year ago [ ] 5 year ago [ ]

c) Type of Floor Covering Material (in Ground Floor):

Cement [ ] Ceramic Floor Tiles [ ]

Clay Floor Tiles [ ] Stone [ ]

Concrete [ ] Wooden Flooring [ ]

Other (Specify) [ ]

……………………………………..

d) Type of Walling Material:

Cement Blocks	[ ]	Bricks	[ ]
Concrete	[ ]	Clay	[ ]
Other (Specify)	[ ]		

……………………………………

e) Type of Roofing Material:

Clay Tile	[ ]	Asbestos Sheet	[ ]
Concrete Slab	[ ]	Metal Roofing Sheet	[ ]
Other (Specify)	[ ]		

…………………………………..

f) Type of Ceiling Material:

Timber	[ ]	Asbestos Sheet	[ ]
Other (Specify)	[ ]		

…………………………………..

g) Type of Doors:

Timber Door	[ ]	Plywood Door	[ ]
Other (Specify)	[ ]		

…………………………………..

h) Number of Doors open to outside:…………………..

i) Type of Windows:

Timber frame with glass	[ ]	Timber	[ ]
Aluminium frame with glass	[ ]	Aluminium	[ ]
Other (Specify)	[ ]		

……………………………………..

j) Number of Windows open to outside:…………………..

k) Percentage of Doors & Windows Opened Daily:

Never	[ ]	25%	[ ]
50%	[ ]	75%	[ ]
100%	[ ]		

6. NORMAL DAILY ROUTING OF THE OCCUPANTS

a) Usage of body spray or hair spray:

Yes [ ] No [ ]

If Yes, how often……………………………

b) Usage of air freshener:

Yes [ ] No [ ]

If Yes, how often……………………………

c) Usage of tobacco smoking:

Yes [ ] No [ ]

If Yes, how often……………………………

d) Usage of insecticides:

Yes [ ] No [ ]

If Yes, how often……………………………

e) Any Chemical fertilizer/insecticide use in the garden:

Yes [ ] No [ ]

If Yes, how often……………………………

7. ANY SYMPTOMS FEEL TO THE OCCUPANTS

	Yes	No
a) Nausea	[ ]	[ ]
b) Dizziness	[ ]	[ ]
c) So throat	[ ]	[ ]
d) Runny nose	[ ]	[ ]
e) Sore Eyes	[ ]	[ ]
f) Lethargy	[ ]	[ ]
g) Headache	[ ]	[ ]
h) Thermal discomfort	[ ]	[ ]
i) No effect	[ ]	[ ]

Annex IX

Measurements of Outdoor Conditions

Measurements of Outdoor conditions

Time	Site 01				Site 02				Site 03				Site 04				Site 05			
	CO_2 (ppm)	Dry Bulb Temp. (^0C)	Wet Bulb Temp. (^0C)	Lux Level (kLux)	CO_2 (ppm)	Dry Bulb Temp. (^0C)	Wet Bulb Temp. (^0C)	Lux Level (kLux)	CO_2 (ppm)	Dry Bulb Temp. (^0C)	Wet Bulb Temp. (^0C)	Lux Level (kLux)	CO_2 (ppm)	Dry Bulb Temp. (^0C)	Wet Bulb Temp. (^0C)	Lux Level (kLux)	CO_2 (ppm)	Dry Bulb Temp. (^0C)	Wet Bulb Temp. (^0C)	Lux Level (kLux)
9:30	404	28.0	26.0	5.90	416	27.0	26.0	10.18	394	28.0	26.5	22.1					406	31.0	26.0	92.5
10:00	414	28.0	26.0	61.10	404	28.5	26.5	17.45	390	29.0	26.5	42.1	413	33.0	26.5	95.5	409	34.0	27.5	95.6
10:30	414	28.5	26.0	14.50	416	29.0	27.0	10.16	406	29.0	27.0	40.2	421	34.0	28.0	105.0	404	32.0	26.5	101.1
11:00	413	28.0	26.0	16.10	420	28.5	27.0	16.11	402	30.0	27.0	54.0	414	32.0	26.5	38.0	406	33.0	27.0	85.5
11:30	415	28.5	26.0	43.20	415	28.5	27.0	10.08	404	30.5	27.0	87.0	420	34.5	28.0	120.3	407	33.0	27.0	106.5
12:00	414	28.0	26.0	54.00	409	28.5	27.0	12.82	404	30.5	27.0	110.0	415	34.5	28.0	115.0	403	33.5	27.0	105.3
12:30	411	29.0	26.5	71.20	415	28.5	26.5	11.92	404	30.0	26.0	30.3	415	35.0	28.0	110.1	408	33.5	26.5	101.4
13:00	411	28.5	27.0	13.20	418	28.5	26.5	11.61	403	29.0	26.0	21.5	417	36.0	28.0	108.1	408	35.0	27.5	95.8
13:30	411	29.0	26.5	12.56	410	28.5	26.5	11.12	405	29.0	26.0	19.6	421	37.0	27.5	105.6	407	34.0	27.0	87.5
14:00	408	29.5	26.5	11.10	411	28.0	26.5	9.87	405	29.0	26.5	16.2	417	36.5	26.5	92.2	405	34.5	27.0	73.4
14:30	412	29.0	26.5	9.45	423	28.5	26.5	12.75	403	29.0	26.5	19.2	418	36.5	27.0	86.9	407	33.0	26.5	79.6
15:00	405	29.0	26.5	29.10	439	28.5	26.5	13.41	405	29.0	26.5	19.2	421	36.5	28.0	27.1	401	34.0	26.5	53.6
15:30	411	28.5	26.0	3.75	439	29.0	26.5	15.91	403	29.0	26.5	18.0	411	35.0	27.5	64.5	408	31.0	26.0	19.8
16:00	413	28.0	26.0	2.15	431	29.0	26.5	12.75	401	29.0	26.5	14.2	409	32.0	26.5	15.2	408	31.0	26.0	33.9