Health and Comfort Implications of Indoor Air Quality and Thermal Conditions in Dubai Elementary Schools

ملاحظات الصحة و الراحة بخصوص كيفية الهواء و ظروف درجة الحرارةالداخلية في مدارس دبى الابتدائية

By

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Table of Contents

Abstract

Many studies indicate that poor indoor air quality and thermal discomfort can negatively impact the health, performance, and comfort of the occupants. Poor quality of indoor air can cause short-term or long-term health problems for students and teachers, and this may result in low attendance rate. Thus, it is important for the school to create and maintain a good and healthy indoor environment in order to accomplish its core mission of educating children and improving their academic achievement. This study presents the findings of investigation into the thermal comfort condition and Indoor Air Quality (IAQ) in four public primary schools across Dubai. Two classrooms were investigated in each school for 6 hours. The schools for this study were selected with the help of Knowledge and Human Development Authority (KHDA).

Qualitative (survey questionnaire) and quantitative measurement (field measurement) were conducted in order to evaluate thermal comfort condition and quality of the indoor air in selected classrooms. Physical parameters (indoor air temperature, relative humidity, and air velocity) and chemical pollutants (CO_2, CO, O_3, TVOCs, and TPM) were measured in selected classrooms. Hence, the main parameters that impact IAQ and thermal condition were investigated and key findings were as follows: Indoor level of Total particulate matter (TPM), Total Volatile Organic Compounds (TVOCs) and CO_2 concentrations in some schools were found to be high. Polluted indoor air was caused either by indoor (e.g. detergent and deodorizer) or outdoor activity (e.g. idling vehicles). Indoor level of contaminants even lower than threshold limits may lead to physiological health symptoms for sensitive individual. The observed IAQ measurements in these schools were found to be correlated with reported symptoms (most especially among sensitive students) like headaches, tiredness, concentration problems, sneezing,

coughing, and eyes and skin irritation. Generally proportion of students who were contented with thermal conditions of classrooms was higher than students who were not pleased.

Findings from this study can assist primary schools in Dubai to improve their indoor environmental quality and maintain a clean and healthy classroom. In addition, findings from this study can help people in charge and policy makers in developing adequate IAQ guideline in order to create a good and comfortable indoor condition for classrooms across the UAE.

ملخص البحث :

يشير العديد من الدراسات إلى أن سوء كيفية الهواء و درجة الحرارة الداخلية للبيئة من شأنه أن يؤثر سلباً على سلامة الأهالي و أدائهم و راحتهم .

إن الوضع المتدني لنوعية الهواء الداخلي من شأنه أن يتسبب في مشاكل صحية على المدى القصير أو البعيد للتلاميذ و المعلمين مما قد يؤدي إلى تقلص حجم ساعات الحضور في الصفوف .

و عليه ، فإن توفير و صيانة بيئة جيدة و سليمة يكتسب أهمية كبيرة لتحقيق المهمة الأساسيةو الخطيرة لتعليم الأطفال و تحسين نجاحاتهم الدراسية.

تقدم هذه الدراسة معطيات بحث عن الظروف و الراحة الحرارية و كيفية الهواء الداخلي في أربع مدارس حكومية للمرحلة الابتدائية بمدينة دبي حيث تم إجراء البحث في كل مدرسة على صفين كل منهما لمدة ست ساعات ، و قد تم اختيار المدارس هيئةالمعرفةوالتنميةالبشرية ، و قد تم إجراء التقدير النوعي(من خلال الاستبيانات البحثية) و المذكورة للدراسة بتعاون من التقديرالكمي (القياس في الموقع) بغية تقييم الظروف الحرارية للراحة و كيفيةالهواءالداخلي في الصفوف المختارة .

و في هذا الإطار تم قياس المتغيرات الفيزيائية في الصفوف المختارة (درجة حرارة الداخلو الرطوبة النسبية و شدة تيار الهواء) و الملوثات الكيمياوية(CO2، CO، O3، TVOCS، TPM) ، و تمت بالتالي دراسة المتغيرات و العوامل الرئيسية ذات التأثير على كيفية هواء الداخل و الظروف الحرارية ، و المعطيات الرئيسية عبارة عن :
كان المستوى الإجمالي للمواد المكونة من جسيمات (TPM)و الكمية الإجمالية للمركبات العضوية المتطايرة (TVOCS) و نسبةCO2 عالية في بعض المدارس. كان الهواء الملوث في الداخل إما ناجماً عن النشاطات الداخلية (مثل استعمال المنظفات و مزيلات الروائح) أو عن النشاطات الخارجية (مثل وسائل النقل المركونة الشغالة) .ان ملوثات الداخل حتى وإن كانت نسبتها أقل من الحدود المسموحة قد تترك أعراضاً و مضاعفات ضارة للصحة الفسيولوجية لدى الأفراد ذوي الحساسية .

و كان هناك تطابق بين الكميات المقدرة عن نوعية الهواء داخل تلك المدارس و الأعراض المذكورة في التقارير (خاصة لدى التلاميذ ذوي الحساسية) مثل أوجاع الرأس و التعب و الإرهاق و مشاكل التركيز و التعطي و السعال و مشاكل في العين و الجلد . و بصورة عامة كانت نسبة التلاميذ المرتاحين تجاه الظروف الحرارية في الصفوف أكثر من التلاميذ غير المرتاحين .

إن نتائج هذا البحث من شأنها أن تساعد المدارس الابتدائية في دبى في تحسين نوعية بيئتها الداخلية و إيجاد صفوف دراسية سليمة و نظيفة . و فضلاً عن ذلك ، من شأنها أيضاً أن تساعد المسؤولين و واضعي الخطط و السياسات في إعداد نظام نوعية هواء الداخل لتوفير أجواء و ظروف طيبة و مريحة في صفوف الدراسة في أنحاء دولة الإمارات العربية المتحدة .

List of Table: ....

List of Figure:

Chapter 1: Introduction

1.1 Brief Overview

Numerous articles stated that people spend more than 90% of their life in an indoor environment. Even though it is such a generalised idea and it may not be a very accurate statement, but it clearly strikes a chord and indicates the importance of Indoor Environment Quality (IEQ). Modern life health issues related to indoor environments are mainly caused by two major shifts caused by industrialization during the last half century. The amplified quantity of time a person spends in indoor space, and the reliance of the individual on synthetic goods. After the end of Second World War, the remarkable change from rural to urban way of life style occurred. Since then, work turned into primarily, an indoor activity. Therefore, the quantity of time a typical individual spent in an indoor environment noticeably increased. Since the end of 1940s, the chemical manufacturing has gone through extensive growth. This drift has created incessant incursion of artificial chemical goods into market such as cleaning product, construction materials, makeup products, textile and fashion goods. Sadly sometimes chemical goods adversely affect the health of individuals since the human body cannot cope with the chemical impact of these products (Lee et al, 1996). Those having problems because of their sensitivity to the living environment perhaps are a warning sign to others regarding the progressively more contaminated environment.

Occupant's density in school classrooms is generally more than other type of rooms (in the office the bedroom, hospital room etc), so students have less space compared to other individuals in different indoor environments. Children are more vulnerable to polluted environments; therefore, a comfortable and healthy indoor environment in school is fundamental for maintaining young minds and bodies and keeping them healthy and energetic; thus the quality of an indoor environment in schools can impact highly on the education of the young generation. California Integrated Waste Management Board (CIWMB, 2010) defines Indoor Environmental Quality (IEQ) as all environmental aspects of the building's interior that influence comfort and/or health of occupants. IEQ consists of aspects such as acoustic quality (noise level), indoor air quality (IAQ), thermal quality, visual/lighting quality and spatial quality. The school building's envelope design, construction process, choice of material, maintenance and operations has an effect almost on all IEQ aspects. Proper management can assist to increase comfort level and decrease disruptions. In addition, it sustains occupant's wellbeing. Each and every one of IEQ aspects react and interact with each other in order to create a healthy and sustainable indoor environment for the school building but this research is mainly focused on the thermal quality and the indoor air quality of classrooms in school building.

1.2 Indoor Air Quality and Its Impacts on School Children

Indoor Air Quality (IAQ) is defined as the quality of air in an indoor environment. According to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) acceptable indoor air quality must have two qualifications. The level of dangerous pollutants must be within the health authority acceptable range and more than 80 percent of occupants, who have been in contact with it should express satisfaction (Damiano, et. al, 2002).

IAQ problems are caused by the release of the particle or gases from contaminant sources. In fact, there are many varieties of contaminant sources and each contamination has a different effect on the human body, but usually indoor air contaminates are divided in four categories: inorganic chemical/compound, organic chemical/compound, particulate matter and microorganism.

1. Inorganic Compounds: Usually is defined as compounds that do not hold carbon hydrogen bonds in their molecular formation. NO_2, CO, CO_2, SO_2, ozone (O_3), and radon are among the most common indoor air contaminates.

2. Organic Compounds: In organic compounds molecules carbon bonded to hydrogen therefore they are called hydrocarbons. Volatile organic contaminants (VOC) are the most common organic compound in the indoor environment.

3. Particulate Matter (pm): they are made of complex combination of inorganic and organic compounds dust, smoke, smog, mist are common pm in the indoor atmosphere.

4. Biological Contaminants: Micro-organisms such as bacteria, viruses, pollen, moulds, dust mite (Jang, et. Al, 1997; Lee et al, 1996).

Airborne contaminants whether big or small may harm human health but very small particles that can reach the deepest part of the human lung and pass through the blood stream are a major health concern since they can harm the respiratory system and other parts of the human body. The United States Environmental Protection Agency (EPA) considered contaminated indoor air as one of the top five most common environmental health threats (EPA, 2010a).

Poor IAQ can cause severe health difficulties such as Sick Building Syndrome (SBS) and Building Related Illnesses (BRI). SBS is described when occupants feel uncomfortable and experience acute health problems while they are within a certain building environment.

Occupants complain about non-specific symptoms such as fatigue, headaches, dizziness, eye irritation, skin rashes, inability to concentrate, nausea and other symptoms. Generally symptoms are not exclusive to certain sickness and they are not caused by a single pollutant source. However, symptoms disappear as soon as occupants exit the unhealthy site.

BRI is described as the diagnosable illness caused by airborne building pollutants. Illness is not eased by leaving the building and usually a long period of time for recovery may be needed. Exposed people can experience symptoms shortly after the exposure or after an extended period of time. Generally the sickness characteristics are dependent on the existence of certain pollutant inside the building. For example, 'humidifier fever and hypersensitivity' are usually caused by bio-aerosols (Lee et al, 1996). The best solution for the BRI problem is to find what particular pollutant is the reason for the certain illness, and eliminate pollutant source or reduce the release of pollutant source.

Children breathe more rapidly in comparison with adults. They also breathe in more air compared to their body weight. The child's body is weaker than a grown up as their bodily organs are not fully developed yet. While an adult's breathing zone is a minimum of one metre above the ground, children's breathing zone is more close to the ground; therefore, they may not only breath the small particle, but also heavier airborne pollutants that hover closely to the ground. In addition, their body may not be able to detoxify many of the common airborne contaminants. Because children are very sensitive to polluted indoor air, they are at higher risk of health issues compared to the grown person. They spend most of their time in a school building, thus appropriate IAQ for school environment is an exceptionally important matter. The indoor conditions of the school building can precisely affect the student's behaviour and academic success (Earthman, et al. 1995). Children who study at a school with IAQ problems have a low attendance rate (Heath and Mendell, 2002). They usually suffer from health issues, so they miss attendance. In addition, a decline in their performance and productivity is very possible. Therefore, IAQ problems in classrooms can negatively affect the children productivity, comfort, health and performance. IAQ contaminant in a school building is usually caused by improper use of cleaning or chemical product, inadequate Heating, Ventilation and Air Conditioning (HVAC) system, water leakage through the building envelope, wrong choice of the building material and furniture, and notably improper maintenance. Accordingly studies on the level of maintenance in a school building demonstrate that students in schools with improved maintenance level have a higher academic achievement, enhanced health conditions and superior class attendance (Earthman, et al, 1995).

1.3 Thermal Comfort and Its Impacts on School Children

Thermal Comfort (TC) is a psychological condition in which individuals feel thermally satisfied with the environment. Thermal comfort is dependent on different factors such as air temperature, air movement, radiant temperature, relative humidity, type of clothing and the type of individual activity. In order to feel thermally comfortable all the above mentioned factors should be in balance with each other, so the human body feels no tension to decrease or increase the body temperature. The human body loses heat through convection, conduction, evaporation and radiation. Thermal comfort is usually measured by the number of people who complain about discomfort.

Having no physical illnesses is not enough to determine a healthy human being. Feeling physiologically well and comfortable is crucial to verify human health condition. Therefore, inappropriate environmental problems such as Thermal comfort can adversely impact human health and comfort. Studies demonstrate that a high-quality educational environment needs no thermal stress. While the human body is not thermally satisfied, it sends the stress sign to the brain. As a result, brain's central processing unit restricts the average function of the brain (Chan and Petrie, 1998). Problem with thermal condition is very important issue because it can affect the performance of the occupants at any age ranges or any ethnicity group. As their level of discomfort increased their productivity and work motivation declines. People have different temperature preferences, so there is no certain temperature that can satisfy all of them. Young minds can easily get distracted by the Thermal comfort problems. Students who feel thermally uncomfortable do not perform and behave well in school. They are not able to fully concentrate in a very hot or cold room (Earthman, 2002; Lawrence Berkeley National Laboratory, 2010; Narucki, 2008). They can become very aggressive or exhausted when they are not thermally pleased (Canadian Centre for Occupational Health & Safety (CCOHS), 2011) Moreover, problems with thermal condition can impact the tutor's quality of teaching (way of teaching), confidence and helpfulness (Heschong, 1999).

1.4 Motivation for the Study

In 1952 there were not many formal schools in United Arab Emirates (UAE) so the education system in UAE is pretty new. During the 1960's and 1970's, the agenda for the education system extended, so the number of school buildings increased and the education system developed. At this time, schooling system for the primary and secondary is universal

(Embassy of the United Arab Emirates in Washington DC, 2010). The UAE had almost 1500 high schools and primary schools in the academic year of 2003-2004 and approximately 31700 attended those schools (UAE Interact, 2010). The UAE government cares and invests greatly for the education of young people, since they believe the good schooling is the input to the upcoming economy wealth and globalised success (UAE Interact, 2010). A quick growth in population of Dubai has demanded a significant investment and thoughtful concern on education and the educational environment.

Many research studies have been conducted on indoor air quality and the thermal comfort issue for residential and commercial buildings but investigations on school buildings are very limited. Students at the higher educational levels such as middle school or high school must use various classrooms for different subjects during the day, but students at elementary levels spend the majority of their academic year in the same room with the same tutor. Consequently, elementary classrooms are significant environments for children and their teacher in terms of exposure to allergens and contaminant. IAQ and thermal conditions have impact on student's learning abilities, performance and productivity. Therefore, better understanding of the conditions and their impacts on students' health and comfort is essential. Taking action for improvement of IAQ and TC condition in schools is vital to enhance young student's academic performance and wellbeing. Likewise it can help the school financially, since it can benefit the school marketing strategy. In addition, it may help decrease the operations and maintenance costs. Most of the school buildings in Dubai widely utilize air conditioning system because of hot and humid climate of Dubai in majority of the mounts. Thus, improving the physical variable in the school building not only helps its occupants, but also will lead to rationalized usage of energy and adequate HVAC systems.

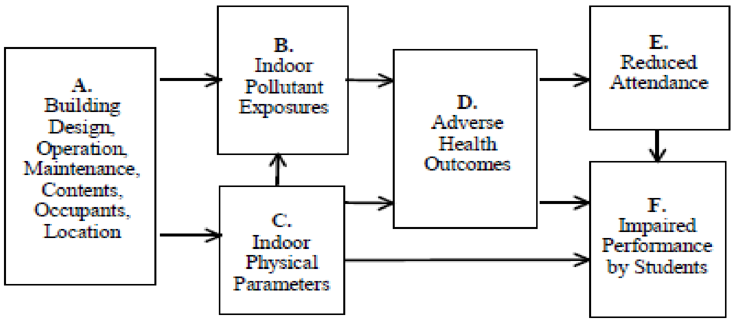


Figure 1.1 Connection between school building characteristics and student (Heath and Mendell , 2002)

1.5 Significance of the Study

IAQ and thermal conditions of Dubai elementary schools' classrooms and their effects on students' health and comfort is expected to be known after the study. Thus, understanding from this research can help policy makers in developing adequate design guidelines that will support health, comfort, performance and productivity in the classrooms. Moreover, it can assist elementary schools in Dubai in sustaining a clean and healthy indoor environment for their classes.

1.6 Outline of the Dissertation

Brief descriptions of following chapters are as follows:

- Literature Review (Chapter 2): Main parameters that impact indoor air quality and thermal comfort condition are briefly described. Relevant published articles about about each parameter that impact IAQ and thermal condition are briefly reviewed.

- Methodology (Chapter 3): Based on the gathered data in the previous chapter (literature review) the most common investigation methods are designated for this study. Investigation methods (walk-through investigation, subjective study and objective study (filed measurement)) which are employed for this study are well defined in this chapter. In addition, the limitations of the study are explained, in order to evaluate this study and enhance future investigation
- Results (Chapter 4): The gathered data from walk-through investigation, subjective study and objective study are analyzed.
- Discussion (Chapter 5): Parameters that impact the IAQ and thermal conditions of the selected classrooms are discussed and compared with relevant studies.
- Conclusion (Chapter 6): Main findings about IAQ and thermal conditions of Dubai elementary schools (classrooms) and their impacts on students' health and comfort are determined. Some strategies are recommended for enhancing the indoor environmental quality in schools.

Chapter 2: Literature Review

2.1 Foreword to IAQ

Indoor air is not necessarily cleaner than outdoor air and it may be even much more polluted. Since typically indoor and outdoor sources of contaminant together contribute to indoor air pollution concentrations. Occupants commonly do not concern about indoor air pollution because air contaminations are not usually visible and some do not have scent. Although, inhalation of contaminants makes occupants sick, the necessity for identifying the pollutant sources and understanding of IAQ problems is an essential because it impacts public health. There are so many studies on the unfavourable health consequences of indoor contamination on adults. They demonstrate a relationship between obtainable contaminant in the air and their side-effects on wellbeing of grown-ups. Nevertheless, they do not consider the fact that health of adult is consequence of lifetime of contaminate disclosure in diverse places. Current location of occupancy perhaps cannot be of a high-quality evaluation for effects of pollutions, but generally children’s health condition reflects a more recent exposure time. Indoor air pollution in their current location of occupancy can determine their health condition. The main sources of children’s health issues are either in their home or schools. IAQ problems in school can elevate occurrence of asthma, contagious, respiratory and allergic illnesses in children.

IAQ in any building is highly related to the following factors: climate, location, construction method, design of the building, building equipments or systems, pollutant sources, building materials and finally the occupants of the building. Therefore difficulty in any of the stated factors can cause the IAQ problems in the school building. Studies use different classifications for the indoor air problems in schools. One of the most organised literature review study on IAQ is done by Shendell et al (2004a). It explained that whether the research on IAQ problems in building is quantitative or qualitative, most of the IAQ studies classify the indoor air problems through particular agents such as chemical agents and particles, biological agents, and physical parameters (physical conditions) . This study follows the same path.

2.2 Chemical Agents and Particles

There are numerous chemical pollutants in the indoor environment. The impact of many of these on the indoor environment has not been sufficiently studied. As a result this study used obtainable data and reviews on the mostly researched and common type of chemical agent in the school's indoor environment such as CO, particulate matters, CO_2, VOC, and O_3.

2.2.1 Carbon Monoxide (CO)

CO or carbon monoxide is an invisible gas without fragrance or taste which is created by deficient burning of carbon holding compounds. General sources of CO emission are tobacco smoke, smoke from most fires, motor vehicles, charcoal grills, industrial combustion, kerosene/ gas stoves, furnaces and space heaters. CO concentration is usually elevated in any internal atmosphere where the combustion engine works with improper ventilation, parking-lot, garage, heavy traffic enclosed area (e.g. road tunnels) and cars (Harrop, 2002).

It can be a highly lethal indoor pollutant. Because the affinity of carbon monoxide to haemoglobin is around 200 times greater than oxygen, inhaled carbon monoxide can dislocate oxygen in haemoglobin. CO attaches tightly to haemoglobin and create carboxyhaemoglobin

(COHb) (Chichkova and Prockop, 2007). In order to be safe, concentration of COHb should be less than 2.5% (Kleinman, 2000a). If it exceeds the certain limit, it may negatively impact fundamental organs of the body through blood stream and causes hypoxia (oxygen deficiency), since it decreases the quantity of oxygen received by major organs and tissues such as brain and heart. Eventually CO can generate respiratory and cardiovascular illness (Chichkova and Prockop, 2007; Paavilainen et al., 2010).

A child's body requires a higher amount of oxygen because their metabolic rate is greater than an adult. Therefore, they are more responsive to elevated CO concentration. Continual disclosure to high levels of carbon monoxide might have enduring health problems for a growing child (Kleinman, 2000a). It harmfully impacts children's nervous system and can cause neurology problems such as decline of IQ level, forgetfulness (memory failure), speech/ hearing destruction and changes in behaviour (e.g. depression) and many other unfavourable conditions (Jain, 1999). However, it is the most widespread kind of inadvertent intoxication in the United States (Piantadosi, 2002). The exact number of people affected by CO worldwide is unknown because the health specialized usually misidentifying the problem. Therefore, it might be the main source of deadly poisoning worldwide (Raub et al, 2000). Gas intoxication caused by CO can have a range of symptoms depending on the length of exposure and the existing amount of CO in the atmosphere. For example, half an hour exposure to atmosphere with 0.3% volumetric CO density can lead to death (Chaloulakou, 2002). Prolonged or long time disclosure to carbon monoxide at low level can have analogous consequences to short time disclosure at elevated concentration level (Malakootian and Yaghmaeian, 2004).

The permitted amount or legal amount of CO has been changed through time in different countries. Different organisations and health care associations suggest various permission limits for CO level in the indoor environment. ASHRAE (The American Society of Heating, Refrigerating and Air-Conditioning Engineers**)** produced a booklet called ‘Ventilation for Acceptable Indoor Air Quality’ (ANSI/ASHRAE Standard 62.1-2004) classifying all the relevant indoor environments guidelines and policies (recommended by various organisations) in which it organises all the approved levels for various indoor contaminants. For example, National Ambient Air Quality Standards (NAAQS) set by EPA recommend 35 ppm (35 parts per million by volume, or 40 mg/m^3) for an hour and 9 ppm (10 mg/m^3) for 8 hours. Occupational Safety and Health Administration (OSHA), which is associated to U.S Department of Labor, forbid worker exposure to CO for higher than 50 ppm for 8 hour length. World Health Organization (WHO) advises 10 ppm for an eight hour time. In countries such as Japan the acceptable limit is 10 ppm, without considering the length of inhalation. So far, the most recommended CO limit for indoor space by specialized researchers and authorize experts such as AHRAE, and EPA is 9 ppm for 8 hours duration, but still this instruction limit might not present sufficient safety code for school children (Etzel, 2001).

There are so many arguments for acceptable CO levels in schools and its connection to attendance rates of its students. Carbon monoxide even at standard limit can still significantly decrease health of school children and increase the rate of absenteeism (Currie, 2009). In Chen et al (2000) study, CO is used as predicator of daily attendance rate in schools, the daily absences’ rate rise 3.79% for every 1 ppm CO increase in the elementary classroom (Chen et al., 2000). Some researchers suggest modifying the limit by considering influencing seasonal variables. Khan (2004) advises guide line for CO pollution should be varied seasonally. Since in cold seasons (autumn and winter) carbon monoxide can hit the highest point and respiratory disease (e.g. influenza) can happen more often. Therefore the pattern of CO contamination may be associated with season-related diseases. However, the limit of 10 ppm may not be appropriate for young people, but most of the studies in the field use it as the acceptable level of safety. It is publicly believed that CO around 10 ppm or lower will not threat any dangerous risk to elementary school children.

Pegas et al (2010) measured the indoor and outdoor air pollutant for 14 schools in Lisbon's urban district with the aim of identifying possible indoor contaminates sources and assessing circumstances contributing to pollution. The results of their study indicate that CO ranges between 1-12.5 (mg/m^3). The highest CO level between all examined schools belongs to the school placed close to the most crowded road of Lisbon city (Pegas et al, 2010). Students, whose school's location was in high traffic density streets, have a low academic achievement compare to others (Egan, and Reilly, 1981). Investigations on carbon monoxide concentration in schools demonstrates that high concentration of carbon monoxide can be result of insufficient ventilation systems in addition to place of intake vents duct close to carbon based fuel combustion (Hilton, 2010). Shendell et al (2004a) said that new studies by the University of California assess the influence of the school buses emissions on children. However, they concentrate on children exposure to various contaminants of the school buses, but their recommendation positively impacts the IAQ conditions in California's school. Since their recommendation lead to helpful policy actions such as decreasing idling time of diesel or gasoline fuel based vehicles near school. In addition, minimum distance between them and building's ventilation means should be 30 metres. Shendell et al study concludes with a mentioned course of action that can decrease indoor concentrations of pollutants such as carbon monoxide, nitrogen oxides and particulate matters. In conclusion; location of school, ventilation system and parking area are main factors affecting level of CO concentration in the school environment.

2.2.2 Particulate matter

Particulates or particulate matter (PM) refers to tiny solid matters (very small particles) or liquid that can be suspended in the atmosphere. Particulates have a multifarious composition of organic and inorganic material. Besides, sometimes they have microorganisms unit. PM is widely recognised as particle pollution. It is similar to the most of the mentioned pollutants, since it is generated either from anthropogenic sources (human activity), or natural sources (e.g. volcanic eruption, wind borne pollen), but mainly it is produced by human activity such as industrial processes, agricultural operations, combustion of fossil fuels, construction procedures, and demolition procedures (Dimari et al., 2008; EPA, 2010b). PM regularly co-occurs and cohabits with combustion contaminants such as SO_2, NO_2, CO, O_3, and acid aerosols.

The existence of combustion contaminates can result in the misdiagnoses of PM toxic effect, since medical symptoms of PM can be mystifying (Matz, 2000). Pollution Prevention and Abatement Handbook by World Bank Group (WBG), EPA and many other scientific sources mentioned that the substantial impact of PM depends on total amount of concentration in the volumetric capacity. A microgram per cubic metre (μg/m3) is a measuring unit for mass concentration of PM in the environment. In addition, it depends on size classification of particles. Dimension or size of the particle is usually used for classification of the particles. First, particles with aerodynamic diameter of greater than 2.5 micron or micrometer (μm) and smaller than 10 μm (2.5<particle<10) are usually referred as course particle (PM_{10}). The main sources of PM10 are windblown particles from the ground or mechanical procedure such as grinding and industrial cutting (EPA, 1997a; Fierro, 2000; Matz, 2000; WBG, 1998). The work of Kleinman (2000b) reviews the PM_{10} study done by The American Thoracic Society's Environmental and Occupational Health Assembly. The study mentioned that daily flux of PM_{10} in the living environment can cause diminish of air flow rate in the lungs of children which result in severe respiratory illness and decreases school attendance. Secondly, particles with of diameter of smaller than 2.5 μm are called fine particles (PM2.5).

Finally, ultra fine particle are those with diameter of less than1.0 μm (EPA, 1997; Fierro, 2000; Matz, 2000; WBG, 1998). Major sources of fine and ultra fine particles are combustion processes. Latest assumption is that smaller particles are more hazardous because as they get smaller their velocities become greater, which can result in penetration to the deepest area of the lung (Reich et al, 2008). When they are very small they can cause cardiovascular and respiratory health issues. Sometimes, at high indoor concentration or a weak health condition of individuals, they can lead to mortality. Particles larger than 10 micron usually get expelled from the body. Therefore, they are not considered as harmful as PM_{10}, $PM_{2.5}$, and $PM_{1.0}$. During 1970's NAAQS (The National Ambient Air Quality Standards) set up total suspended particulates (TSP) measurement. TSP counts for the entirety of particles of different diameters. It contains the large particle which may not be a concern for human health thus many countries do not accept the TSP as a valuable exposure indicator but still there are countries in the world that use TSP system as a standard PM indicator. In 1980's and 1990's NAAQS set up new standard measurements called PM_{10} and $PM_{2.5}$ which replaced TSP standard system. Suggested air quality standard for daily average PM_{10} is 150 µg/m3 and yearly mean is 50 µg/m3. $PM_{2.5}$ daily average limit is 65 µg/m3 and yearly average is 16 µg/m3 (EPA, 1997a; Fierro, 2000; Matz, 2000; WBG, 1998). Unfortunately, the entire standard for PM levels are for ambient air therefore there is no specific guideline for indoor environment.

Indoor level of particulate matter in classrooms is the outcome of both outside and inside building pollutants sources. PM indoor level can be correlated to the number of students, activity level of occupants, HVAC operating system, general maintenance, cleaning, age of school structures, the location of the school and its furnishing. In a small complicated environment such as classroom even cleaning and walking can be reason of growth for particulate matters (Fromme et al. 2007). Though, the major sources of particulate matter are usually outdoor sources but they can easily enter the school indoor space and create a catastrophic indoor air condition.

Dust particularly dust attached on outfits/shoes and chalk dust can be common classroom's PM pollution (Matz, 2000). Occupants of the building can play the role of mobile contaminants suppliers since they bring in outside pollution, but usually there is no accurate source or reason for existence of high PM levels in the indoor environment. There are many studies on outdoor and indoor PM concentration of schools for various locations and possible various particulate matter sources. One of the studies demonstrates that concentration of $PM_{2.5}$ and PM_{10} in elementary classrooms across United States are generally greater than outdoor. The researchers mention that both $PM_{2.5}$ and PM_{10} concentrations in the American schools are higher than typical in an American office. Therefore, children are more at risk. Deplorable ventilation, insufficient floor and furniture cleaning, improper air filtration probably can clarify the situation (ligman et al, 1999).

Diapouli et al (2008) compared the concentration of standard PMs for few Athena's primary schools. They constantly measured the $PM_{2.5}$ and PM_{10} for both indoor and outdoor space via Dust-Trak monitoring device. Fractions of mean indoor PMs over mean outdoor PMs (indoor/outdoor) were approximately equal or higher than 1 for each of the studied schools. It determines that indoor PM is not inevitably lower than outdoors. They conclude that PM levels not only can get affected by outdoor pollutants but also it can remarkably get affected by occupants and density of their work. Halek, et al (2009) measured the PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ during winter time for five elementary schools in the most polluted area of Tehran. The mean indoor and outdoor concentrations of studied PM were as followed. Mean PM_{10} concentration 274µg/m3 Indoor and 140 µg/m3 out- door. Mean $PM_{2.5}$ for indoor space was 42 µg/m3, and 38 µg/m3 for outdoor space. In that order $PM_{1.0}$ was 19 µg/m3 and 22 µg/m3. Their Study demonstrates the high concentration of PM at various sizes in classrooms which can make the indoor environment potentially much more risky than outdoor for children. Therefore, possibility of students getting sick is especially high (Halek et al., 2009). Verifying the precise factors influencing high concentration of particulate matters in the classroom is not possible, since various parameters (indoor and outdoor) can impact the indoor PM level.

2.2.3 Ozone (O_3)

Ozone is a colourless (O_3 is pale blue in high concentration) highly reactive, unstable, poisonous gas with the strong irritating odour in high concentration. O_2 has a diatomic form and contains 2 oxygen atoms while each molecule of ozone has 3 oxygen atoms and it has triatomic form. This additional atom of oxygen can easily re-attach to molecules of various chemicals. Therefore, O3 is extremely reactive gas. (EPA, 2010c; Hill, 2010). Sometimes O_3 can be beneficial for example ozone layer in stratosphere. It is naturally shaped in upper atmosphere, where it creates a shield to protect earth from harmful ultra violet radiation. Ozone in lower atmosphere (ground level, troposphere) is considered as air pollutants. In lower atmosphere it is created by complex photo-chemical combination of hydrocarbon compounds (VOCs) and nitrogen oxides (NO_x) (Hill, 2010; Lee et al, 2004; Shaughnessy, 2006). O_3 is major constituent of smog. Its occurrence in troposphere is escalating and extending. Elevated ozone concentration requires more attention; however, various oxidizing contaminants are considered as air problems (Long and Naidu, 2002). The concentration of the ozone can fluctuate during the various time of the day, different seasons and available amount of VOCs and NO_x in the environment. Usually the greatest level of O3 occurs during hot summer afternoons (European Collaborative Action (ECA), 2007).

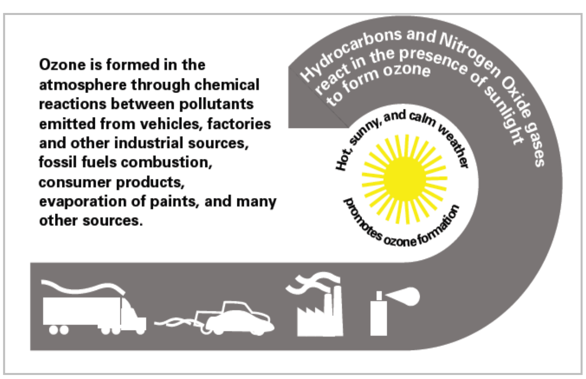


Figure 2.1: Ozone formation (Air Resources Board of California Environmental Protection Agency (ARB/CEPA), 2008).

Normally ozone is carried from outdoor to indoor spaces by ventilation means (e.g. Air-conditioning, windows and doors). Outdoor concentration and indoor suppliers of ozone can determine the fluctuation of O3 concentration in the building interior. Investigators use the indoor/outdoor (I/O) ratios to analyse the buildings ventilation rate. Usually derived from outdoor to indoor air exchange the I/O ratios are around 2/10 (low air exchange) to 7/10 (high air exchange). As a result 2 to 40 parts per billion (ppb) can be added to indoor space depending on the ventilation exchange.

Furthermore, O3 indoor magnification can be caused by different kinds of electronic machines (Shaughnessy, 2006). They can release unsafe amount of ozone into the indoor environment. They impact the indoor concentration of ozone, even though mostly outside sources are defined as major indoor ozone inputs. One of the major sources of ozone in the indoor environment is ozone generating air cleansers (certain air purifier) (European Collaborative Action, 2007; Shaughnessy, 2006). While it operates, it can produce O_3 as a result of the air ionization (Britigan et al, 2006). Office equipment such as a printer (laser printer) and photocopiers are other main indoor sources of O_3 (European Collaborative Action, 2007; Shaughnessy, 2006). Department of Environment and Resource Management (DERM, 2011) in the State of Queensland advised some safety instructions for O3 emitting office equipment. Normally laser printers have a special carbon filter to take in ozone. If the filter does not work properly the odour of ozone can be detected easily. Although it has a repugnant smell at elevated concentrations, in low concentration it has a sweet clover smell. The smell is detectable, at low concentration around 10 ppb (Xerox, 2008). It determines that the filter is supposed to be changed immediately. It is advised to put office equipment in the separate area with the proper ventilation. Recirculation of the equipments' discharge by air conditioning system of the building is exceptionally inappropriate and unsafe. The emission must be directly ducted to the outside of the building (DERM, 2011).

Ozone can quickly react with other chemical compounds in the room. If it combines with NO_x, it can produce the harmful chemicals. By products can destructively influence the central nervous system which includes the brain and spinal cord (London Hazards Centre (LHC), 2002). Furthermore, ozone can react with VOCs and generates radicals (e.g. OH, RO_2) and stable compounds. Part of the generated pollutants can be extremely irritating for respiratory airway and eyes. For example O3 can react with terpenes (available in cleaning products) and create indoor contaminants such as formaldehyde and ultrafine particles. Many of the generated chemicals cannot be monitored or detected by existing conventional diagnostic methods (Singer et al, 2006; Gundel, 2002; European Collaborative Action, 2007). Plants and different building interior materials such as paint, textile, rubber and metals can be damaged considerably by ozone disclosure. Gradually the exposure impacts the aesthetical and useful characteristics of materials. It can cut down their life expectancy. Therefore, it increases the financial losses by augmenting the expenses on protection, maintenance, and substitution of the damaged goods (Air Resources Board of California Environmental Protection Agency (ARB/CEPA), 2008). Exposure to ozone can create severe health problems for individuals. Breathing the ozone can irritate and inflame different organs of the respiratory system so it creates hardness of breathing and it decreases the lung operation. Because of the inflammation, the respiratory airway becomes narrower and the volume capacity of the airway becomes smaller. It reduces the function of the lung cells it makes them more vulnerable to other chemical and contaminants and biological contaminants.

Consequently it can decrease the power of the immune system. The resistance of the body to infectious diseases and influenza can decline considerably. In asthmatic patients it aggravates their problems. Ozone disclosure not only irritates the lung, throat and nose tissues but it can also create many other health symptoms such as eye irritation, nausea, headache, severe skin rashes (skin inflammation), cough and chest pain. In addition, it accelerates premature ageing of cells (ARB/CEPA, 2008; LHC, 2002; Smith and Zhang, 2003).

Guideline for O_3 exposure has been changed over the past decades. The NAAQS/EPA standard for ozone limit in ambient air is 75 ppb for 8 hours exposure and 120 ppb for an hour exposure (EPA, 2010d). Recently EPA has proposed a new exposure limit which is lower than the approved standard. EPA believes that approved standard has been unsuccessful to form the healthy and safe environment. EPA is planning to reconsider the standard regulation. Therefore, the range of 60 to70 ppb is suggested (Nole and Shprentz, 2010). WHO (2008) advises ozone exposure must not exceed 100 $\mu g/m^3$ (around 50 ppb) for 8 hours. Per 10 $\mu g/m^3$ ozone increase in the environment can amplify daily death by 0.3% and cardiovascular problems by 0.4%. Like most of the stated air guidelines the latest principle for WHO and NAAQS/EPA can be applicable for healthy grown-ups, but it may not be appropriate for young people (infant and children) and elderly because of their sensitivity to the ozone exposure. Unfortunately there is no exact threshold limits for ozone exposure that everyone stays healthy. Each and every person reacts in a different way to ozone exposure. The approved limits may only save the healthy individuals from lung injury and other health problems.

Numerous institutes and academics have been conducting various researches on unfavourable problems caused by outdoor ozone exposure. However, they are not many researches on indoor ozone problems in schools but comparable outcomes and consequences can be expected from studies on outdoor ozone. Researchers such as Myers et al (2007) find the relation between aggravation asthma and outdoor ozone. Myers et al (2007) states that raising ozone level in New Mexico results in increasing health check visits associated with asthma problems. Geyh et al (2000) investigates ozone exposure on children living in different regions of California with highest ambient ozone level.

The study represents one year ozone monitoring for outdoor and indoor. The investigation reveals that between all studied groups, male children are more vulnerable since their ozone exposures are superior. In addition, it is mentioned that personal activity levels and characteristics of living environment can be used to approximate exposure levels. The intensity of health problems associated with ozone exposure is not only related to exposure duration and concentration of ambient ozone but also it depends on factors such as wellbeing condition, activity level, age, genetic and gender. Therefore, health effects of ozone exposure may differ extensively between individuals (GreenFacts, 2005; Imperial Valley Air Quality (IVAQ), 2010).

2.2.4 Carbon Dioxide (CO_2)

Carbon dioxide in the gas form is an inflammable, colourless and normally unscented but in the high concentration it can have acidic smell and taste. It can have natural or anthropogenic emission sources and it is widely available in the atmosphere. Human and animal respiration processes usually are considered as the main natural source of CO_2. In addition, the decomposition of living things (e.g. plants and mammals) in the environment is another natural emission source of carbon dioxide. Man made sources of carbon dioxide are power plant, industrial process, cement production process and vehicle's fuel combustion. Basically, any fossil fuel combustion process can produce CO_2 as a by-product. CO_2 is the major dominant green house gas in the atmosphere of the earth. Increasing carbon dioxide concentration in the atmosphere over the past centuries has been one of the main criticizing environmental issues (Eagleson, 1994; Minnesota Department of Health (MDH), 2010). Very complicated systems manage and control the level of carbon dioxide in the human body. Through the inhalation carbon dioxide gets into the blood stream. Carbon dioxide at low concentration is not poisonous while excess amount of carbon dioxide in blood stream is problematic. It can react with H_2O which is main component of the blood in high concentration level. The elevated CO_2 concentration creates elevated H_2CO_3 concentration in blood plasma. H_2CO_3 shortly change into HCO_3^- and H^+ (Hydrogen ion binds to haemoglobin). The increased acidosis in blood creates acid-base disequilibrium situation and eventually it cause problems in central nervous system (Canadian Centre for Occupational Health & Safety (CCOHS), 1997; Keller et al, 2009; Rice, 2004). Therefore, in elevated concentrations it can be harmful to human health.

Elevated amounts of carbon dioxide in the environment can dislocate the ambient air oxygen and decrease the oxygen concentration for respiratory process. It may cause an oxygen deficiency problem mixed with toxicity problems. Therefore, carbon dioxide is considered as asphyxiant gas which is modestly poisonous. Asphyxia symptoms are notable when ambiance air oxygen becomes equal or less than 16%. However, occupation of carbon dioxide intoxication is exceptionally uncommon. High carbon dioxide concentration at 40,000 ppm is deadly (toxic).

(Illinois Department of Public Health (IDPH), 2011; Rice, 2004). CO_2 at levels below the 5000 ppm may cause acute health problems. Health problems related to carbon dioxide disclosure are different for each individual. Like most of other pollutions it depends on the length of disclosure, concentration level, health condition and intensity of physical activity, body size and age (Rice, 2004).

In the majority of the scientific data, health organization consideration and national or governmental recommendation limit, healthy adults are the subject of carbon dioxide exposure. Thus they neglect the exposure limit and health problems associated with CO_2 for the most sensitive groups such as children. Federal and Governmental agencies such as Occupational Safety and Health Administration **(**OSHA) and National Institute of Occupational Safety and Health (NIOSH) put restrictions guideline for CO_2 disclosure in order to reduce health problems associated with carbon dioxide disclosure in work places. (OSHA) permissible exposure limit of carbon dioxide is 5000 ppm (Time Weighted Average) for a 40 hour a week (8 hour per day) and short term disclosure limit is 30000 ppm. NIOSH recommendations are almost similar to OSHA. NIOSH recommended exposure limit for CO_2 is similar to OSHA for long term exposure, but for short term exposure NIOSH recommends 10 minutes discloser limit for 30000 ppm (Kadiyala et al, 2010; Rice, 2004).

Although concentration less than 5,000 ppm are set as exposure limit, but some studies on concentrations of above 1,000 ppm in schools reports irritation of nose, throat, nasal passages (upper respiratory tract) and eye, headache, sleepiness, exhaustion, and unpleasant body odour among occupants. In addition, it creates the sensation of not fresh air in the classroom (IDPH, 2011; Prill, 2000). Study by Simoni et al (2010) clarifies that children studying in the school with CO_2 concentration greater than 1,000 ppm are drastically at elevated risk of dry cough. In addition, inflammation and irritation of internal nose are very common between them. Therefore, sickness and poor attendance rate among them is very possible. Some investigators believe there is a connection between high CO_2 intensity, and student's productivity and academic achievement (IDPH, 2011; Prill, 2000).

The intensity of CO_2 inside schools depends on ventilation rates, length of stay of occupation in the space, occupants' number (number of occupants and duration of their stay is usually called occupancy pattern), volumetric size of the space, outdoor door concentration and other indoor or outdoor carbon dioxide sources (combustion process: smoking cigarette, heating system, car idling), the outdoor concentration and time of day (Murphy and Bradley 2002; Persily, 2000) MDH, 2010). Normally the indoor concentration of carbon dioxide is more than the outdoor concentration because of the accumulative CO_2 generation by building occupants. CO_2 commonly is used as a marker (indicator) of the IAQ condition and ventilation rate. It can determine whether sufficient amount of fresh outside air has been entered the indoor space. Concentration levels of CO_2 are used as proxy or surrogate for inhabitant-produced contaminants mainly body odour (bio-effluents) and for the air supply rate per occupant (Daisey et al, 2003; CCOHS, 1997; IDPH, 2011; MDH, 2010). According to ASHRAE/ANSI Standard-62.1-2010 the acceptable outdoor concentration of carbon dioxide is usually around 300 ppm to 500 ppm. The percentage concentration is around 0.03 to 0.05. If the percentage concentration is higher than acceptable range, it determines the high discharge of combustion sources. Human body intakes oxygen and generates CO_2 depend on the diet, health, type of physical activity and length of the physical activity. The Metabolic Data chart demonstrates the relationship between the physical activity level and CO_2 production. The carbon dioxide production rate is almost 0.31 L/min to at activity level of 1.2 met units (e.g. low intensity office work activity or mild seated classroom activity). According to filed experiments and Laboratory studies by ASHRAE the outdoor ventilation rate required for per individual to remove the body scent is almost 15 cubic feet per minute (7.5 L/s), when physical activity is low activity. ASHRAE/ANSI Standard-62.1-2010 quotes that in order to avoid the offensive indoor body odour level for building visitors the indoor concentration should not exceed 700 ppm more than the outside concentration. (ASHRAE/ANSI, 2010).

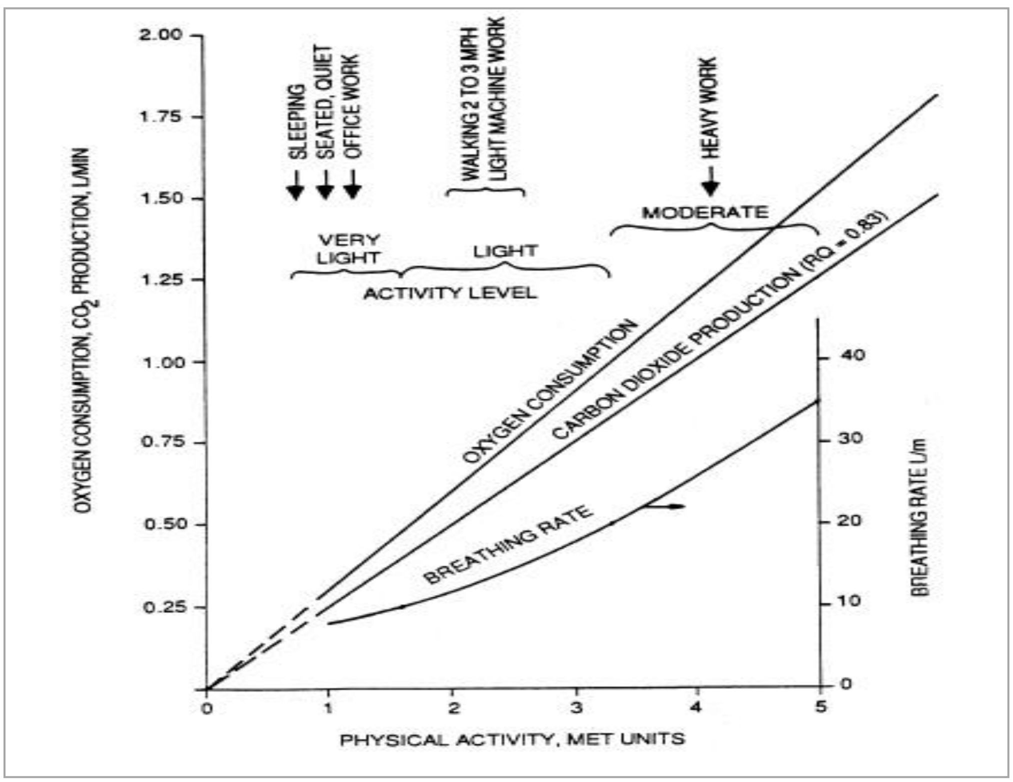


Figure 2.2: Metabolic Data Chart (ASHRAE/ANSI, 2010).

As the physical activity becomes more intense, the CO_2 generation becomes greater. Levels of carbon dioxide in the enclosed area can be in the range of 350 ppm to greater than

1000 ppm in places with high occupancy intensity and high physical activity where proper air ventilation is not provided.

Usually carbon dioxide maximum concentration level recommended for minimizing odour and a comfortable classroom environment (not thermally comfortable) is about 1000 ppm. In most of the US and Canadian studies on carbon dioxide concentration for compliant or non-compliant schools, 1000 ppm concentration is used as upper limit.

Determining the CO_2 concentrations in the classroom is very hard and complicated as they are related to occupancy pattern, ventilation rate and time of the day (Daisey et al, 2003). Indoor carbon dioxide in the elevated concentration can demonstrate inadequacies of the ventilation system. Furthermore, it may point out the existence of other pollutants in the environment since the outdoor fresh air does not circulate properly (not enough outdoor air enter the building) to remove pollutants. However, concentration below the 1000 ppm cannot warranty the appropriate ventilation and good indoor air quality. Since the ventilation rate may not be sufficient to eliminate air contaminants from their sources inside the building. (Daisey et al, 2003; ASHRAE/ANSI, 2010; Canadian Centre for Occupational Health & Safety (CCOHS), 1997; IDPH, 2011; MDH, 2010).

Study by Shendell et al (2004b) demonstrates the correlation between the concentration of carbon dioxide and attendance rate in schools. They gather the attendance data and field measurement indoor-outdoor carbon dioxide concentration data for 22 schools in 2 major states (Washington and Idaho) of United State of America. In class rooms that ventilation rate is less than the recent standard rate and the difference between indoor and outdoor concentration is above 1000 ppm, the student absence rises between 10 to 20 percent. Usually the result of carbon dioxide measurement can help the school to evaluate their ventilation systems. Therefore the result can assist to improve ventilation systems. A monitoring study on elementary schools in Finland result in improvement and change of ventilations means for the class room. The study describes usually carbon dioxide levels in classrooms are at peak during the final hour of the last class lesson. In one of the schools maximum concentrations prior to transformation were reported around 1500 to 1700 ppm. After the renovation of the ventilation system the range decreases to around 650 ppm. (International Energy Agency (IEA), 2003).

2.2.5 Volatile Organic Compounds (VOCs)

Volatile Organic Compounds (VOCs) are chemical organic compounds released from specific fluid or solid materials. They can be off-gas from natural (biogenic) sources and human activity derived materials such as power plants, human made chemical materials and automobile exhaust (Hawas al., 2002). There are numerous VOCs available in the environment. Indoor amount of various poisonous VOCs can go beyond the outdoor level because of restricted indoor capacity size, poor HVAC system and several indoor building contaminant sources. Many of them have an unpleasant odour (Levin and Hodgson, 2006; Building Automation Products, Inc (BAPI), 2010). Some common VOCs and their common sources in the indoor environment are shown in the below Table.

Table 2.1: Indoor VOCs and their sources. (Building Automation Products, Inc (BAPI), 2010).

Typical Indoor Contaminants (VOCs) and Their Source		
Contamination Source	Emission Source	VOC
Human Being	Breath	Acetone, Ethanol, Isoprene,
	Skin Respiration & Perspiration	Nonanal, Decanal, alpha-Pinene
	Flatulence	Methane, Hydrogen
	Cosmetics	Limonene, Eucalyptol
Consumer Products	Household Supplies	Alcohols, Esters, Limonene
Office Equipment	Printers, Copiers, Computers	Benzene, Styrene, Phonole
Combustion	Engines, Appliances, Smoke	Unburnt Hydrocarbons
Building Materials	Paints, Adhesives, Solvents, Carpets	Formaldehyde, Alkanes, Alcohols, Aldehydes, Ketones, Siloxanes
Furniture	Poly Vinyl Chloride (PVC)	Toluene, Xylene, Decane

In most of indoor spaces there are numerous chemical sources that emit different VOCs, so people may be exposed to a variety chemical which emit 50 to 300 various VOCs. Sometimes a mixture of these chemical compounds can develop an unpleasant scent which displeases the occupants (Bernstein et al, 2008). VOCs typically have low boiling points ranges around 50 to 260 °C and high vapour pressure. They can simply vaporize into the environment at typical room temperature with normal conditions (Heiman, 2007) and then they can easily enter the human body via inhalation, ingestion and skin contact. They are publicised as the major indoor pollution, since they can harmfully impact the health of individuals. Health consequences of VOCs after exposure depends on three factors: toxicity level of available VOCs, the duration or period of the exposure and the concentration level of VOCs. Various VOCs are assumed to be carcinogenic. Temporary exposure to low concentrations may not be dangerous for individual health, but continuing and enduring contact (exposure) can possibly cause cancer. In addition they may cause mutagenic problems (Son et al, 2003). Usually Sick Building Syndrome (SBS) problem can indicate the exposure to VOCs. Some of the instantaneous symptoms related with VOCs exposure are tiredness, irritation (inflammation) of upper respiratory tract, eyes, and skin, headaches, nausea, faintness, blurred vision, loss of memory, ataxia (unsteadiness), and shortness of breath. Exposure to VOCs can damage vital organs of the body such as the kidney and liver. In addition it can harm the nervous system, brain and spinal cord (Son et al, 2003; Mølhave et al, 1997; EPA, 2010e).

In order to cut down the lengthy list of indoor VOCs in most of the scientific publications and academic studies, the term 'Total Volatile Organic Compounds' (TVOCs) has been used. It designates the total indoor concentration of all measurable VOC's (Mølhave et al, 1997). TVOCs does not recognise and classify the amount of each and exact available compounds, since it is moderately rough and simple overall measurement. However, there is enough proof to build a relationship between escalating TVOCs concentration and the probability of escalating occupant health problems, but it is not possible to set TVOCs guideline value based on toxicological background because of variety of indoor VOCs and changeable composition of the VOCs combination happening in the indoor environment (Levin, 2010). Therefore, not many guidelines are available for TVOCs. Unfortunately explicit guideline for TVOCs concentrations have not been set by any US or Canadian national or governmental organisations. Therefore, there are no recommended exposure policies for TVOCs in US and Canada (EPA, 2010e). In 2004, the Ministry of Health, Labour and Welfare of Japan recommend maximum (MHLW) 400µg/m3 (0.4 mg/m3) for long term exposure to TVOCs. The standard limit is not primarily derived from toxicological data, but it is practically lowest feasible indoor concentration derived from studies on indoor concentrations of VOCs in Japan. In 2003, Indoor Air Quality Management Group associated with the Government of the Hong Kong Special Administrative Region advised guideline values for good IAQ. In the guideline is suggested that TVOCs should not exceed 600 µg/m3 (Charles et al, 2005). Some studies claim that low concentration of TVOCs even lower than the mentioned exposure approval level possibly will enhance the risk of getting asthma at childhood age. Exposure to TVOCs higher above µg/m^3 can amplify youngsters' risk of getting asthma (fourfold). Investigators believe that assessing the TVOCs can undervalue and misjudge the dangerous threats related to each Volatile Organic Compounds (Rumchev et al., 2004). Many of the IAQ experts employ Lars Mølhave, TVOCs guidelines for evaluating the concentration of TVOCs. Mølhave standard limits unlike other guidelines are based on exposure to different amount of TVOC (total concentration of most occurring VOCs in the atmosphere of building interior) and mucous membrane irritating reaction (Barrett and Barrett, 1995; Envirochex, 2008; Rothweiler et al, 1992).

Table 2.2: Mølhave Guideline for TVOC (Envirochex, 2008)

Mølhave Guidelines Total Volatile Organic Compounds (TVOC)	
Exposure Range	**Concentration** (micrograms/meter^3)
Comfort Range	< 200 µg/m^3
Multifactorial Exposure Range	200 - 3,000 µg/m^3
Discomfort Range	3,000 - 25,000 µg/m^3
Toxic Range	> 25,000 µg/m^3

Concentration levels of VOCs in outdoor environments is depended on temperature, climate (meteorology parameters such as wind velocity and rain), season and propinquity (nearness) to sources that generates VOCs. High emitting sources such as industrial procedure (e.g. factories), petrol stations and a high number of vehicles (high fossil-fuel combustion) can extremely affect the concentration of VOCs in the environment. Because of the indoor and outdoor air exchange, the outdoor concentration of VOCs can influence the indoor concentration. Indoor concentrations of the majority of VOCs are usually 5 to 10 times greater than outdoor concentrations (Jones, 1998). Concentration of VOC's in the school building is depended on the indoor presented VOC sources such as construction materials, building equipments, electrical devices, furniture, cleaning products and solvents (chemicals that emit fumes such as glue, detergents perfumes and paint). In addition, occupant's activities (e.g. cleaning, painting, and personal hygiene activity), ventilation rates, atmospheric conditions, closing or opening the windows and doors because of seasonal changes and the size of the indoor environment can impact the indoor concentration of VOCs. Temperature fluctuation, existence of ozone, age of VOC emitting material, moisture and dampness can change the VOC's concentration levels in the indoor environment (Jia et al, 2008; Son et al, 2003).

Cruz-Martínez (2008) evaluates indoor and outdoor concentrations of TVOCs in elementary schools close to industrial region of Puerto Rico. Cruz-Martínez uses the standard limit which is very similar to Mølhave guideline, so she considers levels above the 2500µg/m3 as dangerous. The study demonstrates that in early morning TVOCs of classrooms in elementary school is at peak due to solvents and cleaning products (used for morning cleaning activity). However, the schools are close to industrial area, but apart from morning time in general TVOCs levels during the day are not high (below 2500µg/m3) and may not seriously harm the health of children. Although, concentration even below 2500µg/m3 may be harmful to children due to their sensitivity and lack of proper guideline for children, but Cruz-Martínez evaluation draw attention to one of the most occurring reason for elevated TVOCs in school environment, which is the use of VOC emitting cleaning product. Shendell et al (2004a) says that majority of investigations on elevated VOCs concentrations in schools consider the using of VOCs emitting cleaning product as one of the main problematic indoor air toxin. Insufficient ventilation and cleaning activity which use materials that have chemical compounds and air deodorizers usually can cause elevated indoor VOCs levels in classroom environment.

2.2.6 Formaldehyde (CH_2O, HCHO)

Organic compound referred to as formaldehyde is one of the major health issues concerning indoor chemicals. Manufactured goods that hold formaldehyde can release formaldehyde gas into the atmosphere. It is a flammable and colourless gas with the unpleasant, suffocating smell. Since it not costly it has been used extensively in manufacturing product and construction industry. Usually formaldehyde is measured separately from TVOCs due to its hazardous impact on human health and wellbeing. Exposure to formaldehyde may cause myeloid leukaemia and raise the morbidity and mortality rate. It is associated with lung and nasal cancer (upper respiratory).Therefore; it is recognized as a cancer causing agent (National Cancer Institute (NCS), 2010; EPA, 1997b; Zhang et al, 2009).

Like all other VOCs the adverse health effect of formaldehyde exposure is dependent on concentration levels of formaldehyde and the length of exposure. Exposure to 0.2 mg/m3 (200 µg/m3) can cause eyesight problems as it raises eye sensitivity to illumination (Levin, 1996). NCS (2010) says in sensitive people acute exposure to levels above 0.1 ppm can cause unfavourable health effects such as irritation and burning sensations in the upper repertory tract and eyes, breathing problems, skin rashes and vomiting sensations. The Office of Environmental Health Hazard Assessment (OEHHA, 2000) declares that continual or long term breathing of 0.002 ppm (2 ppb, 3 µg/m3) can harm eyes and upper and lower respiratory tracts in susceptible individuals. Usually creating indoor environment with very low formaldehyde concentrations is especially difficult. Therefore, the OEHHA suggests a concentration level of 23 ppb (0.023 ppm) for an office environment which is usually the lowest attainable concentration in an office environment (Center for Diseases Control and Prevention (CDC), 2008). There are various guidelines for formaldehyde exposure limit. For short term exposure to formaldehyde WHO suggests 0.08 ppm (0.1 mg/m3, 100 μg/m3), while NIOSH recommends 0.1 ppm for short term exposure limit (15 minute) and 0.016 ppm for 8 hourse exposure (Zhang et al, 2009). Most of the conducted studies on formaldehyde measurement in schools report the concentration beneath 0.05 ppm. Because of child susceptibility to contaminants and lack of organ development, the concentration even much lower than 0.05 ppm may raise the threat of getting cancer, sensitization to allergens, and persisting irritation. (Daisey et al, 2003)

It is normally found in indoor furnishing products and consumer product. Indoor sources of formaldehyde are domestic appliances that combust fossil fuel (e.g. gas stove), consumer products (e.g. dishwashing products, nail polish, shoe care products), coatings, smoking tobacco, paints that contain stabilizers, permanent-press textile goods (curtains and clothing), laminated veneer products, some adhesives and glues. The major indoor sources of formaldehyde are press-wood products, since formaldehyde is regularly used as a resin in manufacturing of wood-based composites. Different types of the press-wood have different emitting levels of formaldehyde. Urea-formaldehyde (UF) resin and phenol-formaldehyde (PF) resin are commonly used in the production of wood-based composites. Products that hold UF resin usually have superior emission rates compared to products made with PB resin. Particleboard (PB), hard plywood and medium density fibreboard (MDF) contain UF resin. Usually MDF used in furnishing products is the main supplier for formaldehyde in the indoor environment because of the elevated proportion of urea formaldehyde holding resin. Oriented-strand board and softwood plywood are made with PB resin, so the emission rate is much lower (NCS, 2010; EPA, 1997b; Lee et al, 2008; Mills, 2010).

In order to determine and measure the formaldehyde concentration level, parameters affecting the emission rate must be understood. Formaldehyde emission rate is depended on indoor and outdoor air change (air circulation), humidity, temperature, in addition to age of formaldehyde sources. Inadequate ventilation, high indoor temperature and high indoor moisture can result in increasing discharge of formaldehyde from the source. The concentration of formaldehyde can vary by daylight hours and seasons. It may be very high during a damp and hot day in summer. Investigations on formaldehyde emitting products reveal that emission rate began to decrease 8 months after its manufacture date. As the product's age increases, its off-gassing property declines (CDC, 2008; EPA, 1997b; Mills, 2010; Hodgson et al, 2004). Sohn et al (2009) investigation assesses the IAQ condition in fifty five elementary schools in Korea. Formaldehyde indoor concentration levels are evaluated in relation to different seasons and building age. Indoor/ outdoor concentration ratio of formaldehyde during fall season is around 6.32 % which is the highest measured ratio. Poor ventilation during fall season appears to be the reason for the high ratio. Newly built schools have drastically elevated concentration levels. The mean concentration of formaldehyde is around 0.16 ppm for a one year old building. Appropriate ventilation system in addition to using low-gas-off furniture and construction material can drastically reduce the formaldehyde concentration; therefore, it can improve the IAQ condition of the classrooms.

2.3 Biological Agents

Biological pollutants are referred to very small living creatures and a by-product of living things. Living organisms or micro-organisms consist of bacteria, viruses, fungi (mildew and moulds), protozoa, insects, pollen, insects (cockroaches), mites (dust mite), and algae. Many of them are not easily detectable with the naked eye since their size is microscopic. By products of living organisms comprise urine, saliva, and dander of animals (domestic pet, mice, rats), human dander, insects body part and waste and small matter of plant part (EPA, 2010f; Noyes, 1991 Seltzer, 1994;). Indoor biological contaminants are linked to broad variety of health consequences. Adverse health effects of biological agent are contingent on the kind of biological agent, and presented amount of biological agent. In addition, it is depended on the susceptibility condition of exposed person. Susceptibility of individual to exposure of biological agent is depended on genetic (Atopy), age, health condition and gender (Nevalainen and Morawska, 2009; Pollution, 2010). Building related illness (BRI) is mostly caused by biological pollutant. The largest parts of biological pollutants are not pathogenic, so they do not cause infectious diseases. They can cause health problem only for sensitive or vulnerable individual (CARB, 2005; Noyes, 1991).

Inhaling indoor biological pollutants can cause various health problems such as asthma, allergy reaction, toxic reaction and infectious diseases (California Air Resources Board, (CARB), 2005). They can harm body parts such as the organs of the respiratory system, skin and eyes and cause irritation and inflammation. Mostly indoor air biological pollutants create diseases and problems in the reparatory tract (upper and lower). They can trigger instantaneous hyper-sensitivity reaction, provoke immune system reaction or cause contagion (infectious disease) (Seltzer, 1994). Hyper-sensitivity reaction, hay fever (poll enosis or allergic rhinitis) and some asthmatic problems are associated with allergic response of the human body to biological pollutants. General indicators of allergic reaction due to exposure are dyspnoea, diluted or watery eyes, faintness, exhaustion, runny nose, fever, sneezing, coughing, itching and rashes. Dust-mite, fungi (mould), animal dander, and pollen (usually from outdoor) are the most common indoor allergens. In elevated concentration these allergens can generate severe allergic reactions or can worsen asthma and asthma attack. Normally the sensitization to allergens happens following continual exposures to particular biological allergen. Therefore, individuals without allergy problem or not strong allergy problem to particular biological agent may unexpectedly become extremely responsive and sensitive to that specific agent. Vulnerable people such as children can develop allergic alveolitis (hyper-sensitivity pneumonitis) if they continuously inhale the high quantity of biological allergens (EPA, 2010f; CARB, 2005; Noyes, 1991).

A number of studies assume that inhaling toxins generated by microorganisms can lead to symptoms such as memory impairment, learning difficulty (learning disorder), headaches, shivering, dry cough, nausea, diarrhoea and higher occurrence of infectious diseases (influenza). Stated symptoms can be caused by mycotoxins. It is a poisonous substance which is ametabolic product (resultant, by-product) of some fungi such as mould. It is assumed that in the long run mycotoxicoses poisoning can cause liver cancer. Problem caused by mycotoxins is more common in children than in adults (CARB, 2005; EPA, 2010f; Yang, 1994). In addition, adverse health effect of the disease is more severe between children than adults because their capability to detoxify is much poorer, so children are more sensitive to mycotoxins (Sherif, 2009). It can seriously harm them. Viruses and bacteria are usually carried into indoor environment by people or animals. Pathogenic diseases or transmissible disease can be transmitted easily from an individual to another individual through indoor air. Influenza virus can generate symptoms such as fever, chill, sore throat, pains, coughing, exhaustion and a discomforting strong headache. Aerosols holding the influenza virus can enter the body via nose (respiration), mouth and eyes. Mycobacterium tuberculosis is kind of bacteria that typically attacks the lungs via inhalation and can create deadly infection problems. Studies demonstrate classrooms which are more crowded are more likely to transmit the viruses and bacteria. Therefore, students studying in highly populated classroom with improper ventilation are more susceptible to get infectious diseases (CARB, 2005).

Table 2.3: Typical biological agents, their characteristics, and sources (Seltzer, 1994)

Living source	Airborne unit	Examples of sources	Primary human effects	Lifestyle	Principal indoor sources
Bacteria	Organisms	*Legionella*	Pneumonia	Facultative parasites	Cooling towers
	Spores	*Thermoactinomyces*	Hypersensitivity pneumonitis	Saprophytes	Hot water sources, hot damp surfaces
	Products	Endotoxin	Fever, chills	–	Stagnant water reservoirs
		Proteases	Asthma	–	Industrial processes
Fungi	Organisms	*Sporobolomyces*	Hypersensitivity pneumonitis	Saprophytes	Damp environmental surfaces
	Spores	*Alternaria*	Asthma, rhinitis	Saprophytes	Outdoor air, damp surfaces
	Spores	*Histoplasma*	Systemic infection	Facultative parasites	Bird droppings
	Antigens	Glycoproteins	Asthma, rhinitis	–	Outdoor air
	Toxins	Aflatoxins	Cancer	–	Damp surfaces
	Volatiles	Aldehydes	Headaches, mucous membrane irritants	–	Damp surfaces
Protozoa	Organisms	*Naegleria*	Infection	Facultative parasites	Contaminated water reservoirs
	Antigens	*Acanthamoeba*	Hypersensitivity pneumonitis	–	Contaminated water reservoirs
Viruses	Organisms	Influenza	Respiratory infection	Obligate parasites	Human hosts
Algae	Organisms	*Chlorococus*	Asthma, rhinitis	Autotrophic*	Outdoor air
Green Plants	Pollen	*Ambrosia* (ragweed)	Asthma, rhinitis	Autotrophic*	Outdoor air
Arthropods	Feces	*Dermatophagoides*	Asthma, rhinitis	Phagotrophic†	

Moisture, mould augmentation on surface and the existence of a domestic animal are some observable factors that can indicate the existence of potential biological contaminants. Comprehensively identifying and monitoring a diverse range of biological contaminants inside the building cannot be done by any particular investigation method. Long term monitoring of biological contaminants, proper ways or techniques of sampling is important in assessing exposure problems associated with biological contaminants (Jafta, 2007). Daisey et al (2003). It mentioned that damaging effect of exposure to biological pollutants cannot be determined accurately by monitoring and collecting samples from indoor air because of the shortage of findings from measuring and examining of indoor biological aerosol. Therefore, monitoring the biological aerosol of the indoor air is not recommended by The National Institute for Occupational Safety and Health (NIOSH). It is recommended the use of physical evidence rather than air monitoring. Daisey et al says that many researchers employ the observation assessing method according to the guidelines of 'American Conference of Governmental Industrial Hygienists Bio-aerosol Committee (ACGIH). According to the ACGIH guideline, taking samples from the air can hardly present enough verification for unacceptable exposure to biological contaminant, so air sampling methods is the last alternative. Accordingly observable augmentation of microorganism on surface of indoor materials (e.g. furniture, wall, and floor) can generally provide obvious and apparent proof (fact) for promising problems associated with biological contaminants.

Augmentation and continued existence of microorganisms rely upon dampness and provided organic edible material for microorganism. 'Lag', 'exponential', 'stability 'and 'death' are four phases of endurance (survival) for any microorganisms. For each microorganism passing per phase required certain time. Well-timed dampness management can prevent biological agents to reach the second or third phase. Therefore, their life cycle will be limited (Berry, 2002). In 1991, the European Concerted Action (1991) declared a usual HVAC system diffuses biological agents inside the building environment because of improper operation, design and maintenance of HVAC system. Regularly humidification parts in HVAC system are foundation for microbial pollutants since humidification parts usually supply proper temperature and humidity for growth of infectious agents. Improper operation of ventilation systems (very low ventilation rate) can drastically amplify the risk of infectious respiratory problem between building occupants (Brundage et al, 1998). According to NIOSH water-damaged materials in building environment is one of the major regular problems that affect the indoor air quality (Daisey et al, 2003). In the school environment water-damaged materials that contain nutrients such as cellulose based (e.g. plywood) materials whether in dark areas or light provided areas can offer the prospective reproduction setting for the bacteria and mould. Outcomes of comprehensive studies on changing the water-damaged material and fixing the moisture problems in schools demonstrate an increase in productivity and the learning ability of the students. Because by solving the moisture problem, the students do not suffer any more from inflammation of the internal nose (rhinitis) and impairment and difficulty in concentration (Shendell et al, 2004a). Patovirta (2005) evaluates the health of teacher in mould-damaged school buildings. The study demonstrates that the teacher's health can improve significantly by fixing the moisture problem in school. The occurrence of symptoms such as exhaustion, headache, voice problems and a stuffy nose has been declined after the repairing. Usually the climate, building material, and HVAC system, and crawl space cross-ventilation, personal hygiene can influence the occurrence and intensity of biological agents in a school environment.

The occurrence of biological agents in a school environment can be reduced by the elimination of high indoor humidity, fixing mould-damaged surfaces, improving the HVAC system, preventing water leakage through building envelope, repairing the water damaged materials, practicing adequate maintenance, practicing proper cleaning, in addition to occupants practicing fine hygiene (Shendell et al, 2004a).

Due to measurement difficulties associated with biological agents, this study will not examine and measure the indoor biological agent; in addition it will not evaluate the students wellbeing based on health effect of exposure to bio-aerosol in class rooms. Only visible biological contaminants such as mould- growth on indoor surfaces will be documented and briefly discussed.

2.4 Physical Conditions

In order to create improved IAQ conditions, physical parameters need to be controlled. The outdoor air can highly influence the IAQ condition of the school building, if the building is located in urban polluted district (highly traffic area) or are located near to a highly industrialised district (Guo et al, 2004). Unfortunately the location of the building is a physical limitation that cannot be changed easily, but there are some other influencing parameters that can be controlled. Indoor physical parameters such as temperature, humidity and ventilation (air change rate, airflow rate) can affect both indoor air quality conditions and thermal comfort. Classrooms indoor physical parameters can impact concentration of indoor contaminant and student’s exposure to contaminants. They may have influence on indoor existence of certain kinds of pollutants and its concentration levels. Therefore, physical parameters can directly impact comfort and health of the students. Since they are related to thermal comfort as well as IAQ, in this part of the study they are briefly discussed. `

2.4.1 Humidity, Temperature, and Ventilation

Relative Humidity (RH) is a parameter that can majorly impact IAQ and occupants' wellbeing (Kjaergaard and Wolkoff, 2007). Therefore, managing the humidity of indoor environment is essential for creating appropriate IAQ condition. It can be achieved by maintaining the humidity at proper level (Woloszyn et al, 2009). Low humidity can possibly increase the risk of the dry mucous membranes and xerosis (dry skin). In addition, low humidity can cause upper respiratory tract inflammation and eye irritation (Woloszyn et al, 2009; Bron et al, 2004; Kjaergaard and Wolkoff, 2007). High temperatures and moist air can promote the augmentation of microorganism that can provoke allergic problems (Guo et al, 2004).

Condensation increase on surfaces of interior furniture and materials is an indicator of indoor air with elevated humidity. Severe moisture harms of the building material and augmentation of biological agents are associated high humidity. The investigation on six school buildings in hot and humid regions of Florida demonstrated unpleasant problems linked to improper humidity ranges. As indoor air humidity reaches close or above 69% the following problems has occurred: observable mould growth on interior surfaces, mouldy smells, and occupants' health problems (Bates and Mahaffy, 1996). Presence of occupants (quantity of occupants), activity of the occupants, and some apparatus can affect the level of indoor humidity (Woloszyn et al, 2009;Guo et al, 2004).

Furthermore, ventilation can bring in the humidity content of the outdoor atmosphere, in addition it catch the moisture from materials which attract moisture from the environment (hygroscopic surfaces building exterior and furniture). Therefore, appropriate utilization of the damp-buffering surfaces can result in suitable steady indoor humidity ranges (Woloszyn et al, 2009).

Currently many of the furnishing materials in modern classrooms may generate unpleasant smells and release poisonous pollutants such as VOC's. As it was mentioned before VOC's emission rates are related to indoor temperature, RH and age of the material (Shendell et al, 2004a). Jo and Sohn (2009) study demonstrates a correlation between fluctuation in temperature and humidity and the concentration of certain indoor pollutants (TVOCs, formaldehyde). Decaying curves of TVOC and formaldehyde concentration start to change by escalating temperatures and humidity. Overall outcome of the study demonstrates that the majority of the indoor VOC's concentrations are proportional to indoor relative humidity and temperature. Keeping humidity or temperature at the highest range of comfort precinct has a propensity to raise health symptoms; though keeping temperature or humidity at the lowest range of the comfort precinct have a propensity to decrease health problems (EPA, 2000). Kjaergaard and Wolkoff (2007) say that though some studies on material VOC's releasing suggest dry and cool indoor environment, but people in charge should cautiously consider allergic symptoms related to low humidity range. Therefore, Kjaergaard and Wolkoff suggest no humidity range less than 30%.

IAQ condition is correlated to ventilation. Insufficient ventilation may be an indicator of students' health problems. Improper operation of the ventilation system can lead to moisture and temperature problems (Guo et al, 2004). Correct ventilation systems can enhance the IAQ condition by providing fresh outdoor air for occupants' inhalation, removing high dampness, in addition to reducing and eliminating contaminants (BRANZ Ltd, 2007).

Most of reported studies on schools ventilation confirm ventilation troubles such as improper design, poor operation of HVAC system and lack of maintenance. (Shendell et al, 2004a). The most popular problems of HVAC in schools are inadequate maintenance of HVAC systems. Seldom replacement of filter is exceptionally common in schools. Reactive chemical to ozone such as VOC's and particulate matters are often gathered on the filter of HVAC systems. The earliest main ozone responding surface in the environment are HVAC's filters. Frequently particulate matters and VOC's are placed on filters as the HVAC systems are working. Filters become extremely great effectual panel materials for mixing of ozone with other harmful chemicals. Therefore, HVACs filters are usually a potential for contaminant foundation. Because numbers of occupants in classrooms are higher than many of the same size indoor spaces, usually classrooms are required to have high air exchange rates. Thus, higher exchange rate can transfer supplementary amount of ozone into the filters and indoor environment compared to weaker air exchange rates. Filters are rapidly encumbered with particulate matters since particle concentrations in classrooms are typically elevated. Ozone combines with other pollutant chemicals while air passes through loaded filters. The outcome air from the filter represents a considerable source of 'aerosol particles' and secondary contaminants (Destaillats et al, 2008).

2.5 Foreword to Thermal Comfort

When the indoor environment comprises neither extreme warm nor cold conditions for occupants, it reveals that the indoor ambiance of the place is within the comfort zone of its occupants. Accordingly, within the comfort zone occupants require insignificant or no attempt to adapt their bodies to the enclosing environmental circumstances (Çakir, 2006). In order to achieve preferred thermal sensation, individuals use adaptive techniques to deal with their thermal surrounding. When they cannot to use their adaptive techniques, the thermal discomfort problems occur (Nicol and Humphreys; 2001). Individuals adapt themselves to thermal surrounding by 3 distinctive processes to achieve thermal comfort. Firstly, the most common adaption approach or first process is called control or behavioural adaptation. Individuals apply behavioural approaches consciously by taking actions to adjust themselves to their thermal surroundings. The actions are either personal adjustment (e.g. modifying their activity level, adding or removing layers of clothing, moving away or move closer to heat suppliers, modifying their body posture instinctively, drinking hot beverage), or they are environmental adjustments (e.g. switching on the air-conditioning system, using shade near the window). Secondly, physiological adaptation applies for biological modifications due to lengthened experiencing of extreme thermal quality in the environment. In severe atmospheric environments, the human-body tries to preserve the body core temperature at a practical altitude by forcing the muscular wall of the vessels to narrow or dilate the diameter of blood vessels and sweating. For example, individuals' bodies eventually adjust to hot environment via sweating. Finally, psychological adaptation occurs usually when individuals repeatedly experience the similar environmental situation. It modifies sensitivity and response of bodily conditions caused by prospect or precedent experience. Individuals expectations concerning to climatic variation, seasonal differences, every day habit and ethnicity can possibly impact comfort sensation. In order to feel comfortable during the time that the outdoor climate is moderate, individuals expect minor indoor temperature difference, so they expect a little cooler indoor climate compared to outdoor. In addition, individuals have a natural aversion toward unchanging uncomfortable environmental situation. Unchanging climatic circumstances may cause ‘thermal boredom’ which has following symptoms: laziness, lassitude, slowness, uncaring attitude, idleness and boredom (Nicol and Humphreys, 2001; Yao et al, 2009; Ward et al, 2011; McCarthy et al, 2001).

Since thermal comfort is a mental condition, it is not attached to the equation of energy balances or temperature and mass equations for heat shift. Nevertheless, parameters that influence energy balance equation can impact the comfort sensitivity (Brandemuehl, 2005). In the various climatic circumstances, individual body always tries to maintain the body temperature inside the constricted limit of ± 1°C around the 37°C which is satisfactory steady body core temperature (Epstein and Moran, 2006; Kelvin, 2009). For accomplishing the body temperature equilibrium, individuals need a continuous heat exchange between the surrounding environment and their body. Heat is transferred by surrounding environment with the individuals’ body (thermal stress) and physiological reactions of the body’s (thermal strain) impact the thermal comfort condition for individuals (Jendritzk, and Tinz, 2009). Radiation (warm body surface to cold surface), conduction, convection (warm body surface to cold atmosphere) and evaporation (water evaporation) heat loss influence the heat transfer; consequently they influence thermal comfort.

If the heat produced by an individual's metabolic activity is tolerable to disperse (fade away), it can sustain thermal balance with the setting environment. In the thermal comfort condition the average body skin temperature is around 33° C. Individuals do not experience discomfort while temperature of their body surface is fluctuating around ±1.5 °C. As thermal balance with environment cannot be occurred, it can cause a discomfort feeling (Hussein and Rahman, 2009; Rodeck, and Whittle, 1999; Kelvin, 2009). Feeling thermally uncomfortable possibly will not cause an instant problem in individual's physical condition. Thermal discomfort has an effect on self-esteem, sense of exhaustion, touchiness and bad temper which can decrease human productivity (New Zealand-Department of Labour, 2007). Sustaining stable thermal setting within the work-place is imperative since very slight change from comfortable situation may possibly create tense and hectic situation which influence wellbeing and performance of the occupant. Students who are under strain and tension cannot easily tolerate uncomfortable environmental settings; therefore, if the thermal situation is not within their comfort zone, they suffer more from stress (Canadian Centre for Occupational Health & Safety (CCOHS), 2011).

Assessing and understanding thermal comfort conditions in classrooms is crucial since thermal comfort condition can have a major impact on a student's academic success. Personal factors (activity level, clothing) and environmental factors (physical parameters, air temperature, radiant temperature, air velocity and relative humidity) should be considered for assessing the thermal comfort. All these factors are interrelated and correlated to each others to create thermally comfortable environment. Thus, proper combination of them can result in thermally acceptable indoor situation.

2.6 Personal Factors

Thermal comfort of individuals is affected by activity level, clothing thermal resistance, and individual differences such as body size, gender, age, level of baldness, physical and physiological health (Auliciems and Szokolay, 2007). Knowledge about relationship of each and every of the personal factors to thermal comfort is very limited. Moreover, it is not easy to specify all personal parameters in the thermal environment, therefore, usually the most common and influential personal factors such as garments insulations and activity levels are considered for assessing thermal comfort. Personal factors in school environment may be different widely; consequently the thermal comfort necessities may differ for per individual (EPA, 2009).

2.6.1 Clothing

Some people believe that women typically desire slightly higher temperatures compared to men because of the clothing dissimilarities (Auliciems and Szokolay, 2007). Characteristic of outfits can affect capability of the human body to exchange heat to the surroundings environment. Insulating result of garments on the body can impact the thermal situation of the individual. Garments can influence the heat transfer thus it impact thermal comfort (Levin, 1996).

Using excess garments, thick clothing, or protecting goods (personal protective equipment (PPE), e.g. respiratory protective equipment) may possibly be the major reason for heat problems in the surroundings which is not regarded as hot or temperate (Health and Safety Executive (HSE), 2003). In order to preserve the thermal balance in hot situations, the individual's body should be able to get rid of excess heat. The body produces sweat because it can achieve the cooling result by drying up the sweat from the skin. Wearing high quantity of garments or thick clothing can unfavourably impact the effectiveness of the cooling because it restricts flow of air above the body surface. Vapour permeability limitation of clothing can raise the amount of moisture close to the body surface. Therefore, it is recommended to wear breathable fabrics in hot climates. In cold areas people are wearing more layers of clothing or clothing with thick fabric, in order to create thermal barrier (Australian Governments Bureau of Meteorology (BOM), 2010; HSE, 2003).

Garment insulations are not directly measured in the majority of investigations of thermal comfort because direct assessing can be time consuming and inconvenient. Thus, investigators commonly calculate approximately insulation values by means of ASHRAE garments insulation chart. ASHRAE tables are developed from studies on garments insulation properties (Charles, 2003).

For expressing the thermal characteristics of clothing the intrinsic clothing insulation (I_{cl}) is used. I_{cl} represents resistance property of clothing to heat transfer or effectiveness of garments insulation. I_{cl} is considered from the body surface to the clothing exterior without concerning the air layer. I_{cl} ($\sum I_{clu}$) represents the total of insulation for all pieces of garments while I_{clu} represent insulation value of each piece of clothing. Clothing insulation is estimated in CLO unit or m2ºC/W (Jokl, 2002; ASHRAE/ANSI, 2004).

Table 2.4: 'Clothing Insulation Values for Typical Ensembles' (ASHRAE/ANSI, 2004)

Clothing Description	Garments Included [b]	I_{cl} (clo)
Trousers	1) Trousers, short-sleeve shirt	0.57
	2) Trousers, long-sleeve shirt	0.61
	3) #2 plus suit jacket	0.96
	4) #2 plus suit jacket, vest, T-shirt	1.14
	5) #2 plus long sleeve sweater, T-shirt	1.01
	6) #5 plus suit jacket, long underwear bottoms	1.30
Skirts/Dresses	7) Knee-length skirt, short-sleeve shirt (sandals)	0.54
	8) Knee-length skirt, long-sleeve shirt, full slip	0.67
	9) Knee-length skirt, long-sleeve shirt, half slip, long-sleeve sweater	1.10
	10) Knee-length skirt, long-sleeve shirt, half slip, suit jacket	1.04
	11) Ankle-length skirt, long-sleeve shirt, suit jacket	1.10
Shorts	12) Walking shorts, short-sleeve shirt	0.36
Overalls/Coveralls	13) Long-sleeve coveralls, T-shirt	0.72
	14) Overalls, long-sleeve shirt, T-shirt	0.89
	15) Insulated coveralls, long-sleeve thermal underwear tops and bottoms	1.37
Athletic	16) Sweat pants, long-sleeve sweatshirt	0.74
Sleepwear	17) Long-sleeve pajama tops, long pajama trousers, short 3/4 length robe (slippers, no socks)	0.96

Table 2.5: Garment Insulating Value (ASHRAE/ANSI, 2004)

Garment Description [b]	I_{clu} (clo)	Garment Description [b]	I_{clu} (clo)
Underwear		**Dress and Skirts** [c]	
Bra	0.01	Skirt (thin)	0.14
Panties	0.03	Skirt (thick)	0.23
Men's briefs	0.04	Sleeveless, scoop neck (thin)	0.23
T-shirt	0.08	Sleeveless, scoop neck (thick), i.e., jumper	0.27
Half-slip	0.14	Short-sleeve shirtdress (thin)	0.29
Long underwear bottoms	0.15	Long-sleeve shirtdress (thin)	0.33
Full slip	0.16	Long-sleeve shirtdress (thick)	0.47
Long underwear top	0.20	**Sweaters**	
Footwear		Sleeveless vest (thin)	0.13
Ankle-length athletic socks	0.02	Sleeveless vest (thick)	0.22
Pantyhose/stockings	0.02	Long-sleeve (thin)	0.25
Sandals/thongs	0.02	Long-sleeve (thick)	0.36
Shoes	0.02	**Suit Jackets and Vests** [d]	
Slippers (quilted, pile lined)	0.03	Sleeveless vest (thin)	0.10
Calf-length socks	0.03	Sleeveless vest (thick)	0.17
Knee socks (thick)	0.06	Single-breasted (thin)	0.36
Boots	0.10	Single-breasted (thick)	0.42
Shirts and Blouses		Double-breasted (thin)	0.44
Sleeveless/scoop-neck blouse	0.13	Double-breasted (thick)	0.48
Short-sleeve knit sport shirt	0.17	**Sleepwear and Robes**	
Short-sleeve dress shirt	0.19	Sleeveless short gown (thin)	0.18
Long-sleeve dress shirt	0.25	Sleeveless long gown (thin)	0.20
Long-sleeve flannel shirt	0.34	Short-sleeve hospital gown	0.31
Long-sleeve sweatshirt	0.34	Short-sleeve short robe (thin)	0.34
Trousers and Coveralls		Short-sleeve pajamas (thin)	0.42
Short shorts	0.06	Long-sleeve long gown (thick)	0.46
Walking shorts	0.08	Long-sleeve short wrap robe (thick)	0.48
Straight trousers (thin)	0.15	Long-sleeve pajamas (thick)	0.57
Straight trousers (thick)	0.24	Long-sleeve long wrap robe (thick)	0.69
Sweatpants	0.28		
Overalls	0.30		
Coveralls	0.49		

Garments can be a potential reason for thermal discomfort and garments can also be a potential help to manage thermal comfort. Individuals can thermally adjust themselves to the climate of the surrounding environment by wearing proper amount or type (s) of clothing. If they suffer from cold, they can add another layer of clothing. If they experience heat they can eliminate some of clothing layers (HSE, 2010). Sometimes the thermal comfort problem arises in schools or workplaces where occupants must wear certain types of clothing. Since the capability of occupants for removing or adding garments is decreased they may not be able to make proper adaptations to their environment.

Study by Chun and Kwok (2003) compares schools with specific uniform (natural ventilation) clothing and schools with no dress code school (mechanical ventilation). Uncomfortable thermal situation is claimed by students in school with natural ventilation means which is probably caused by special clothing. Since rating of student's clothing CLO in schools with natural ventilation are reported to be about 0.08 superior to CLO of students clothing in the school with mechanical ventilation. Adaptive approaches for clothing in schools with dress codes are very limited; thus students may not acceptably lose heat. On the contrary it is observed that students in schools with open dress codes feel thermally comfortable since they have awareness on thermal situations in different areas of the school, therefore they can adjust the layers of their clothing in classrooms. They are psychologically ready to handle different thermal situations. Consequently, they can wear an appropriate amount of clothing. For example, if they feel cold in a certain classroom, they wear a sweat-shirt or coat on top of their t-shirt.

Newsham (1997) declares that modification of clothing in workplace can be possibly the most imperative obtainable comfort adjustments for the occupants. Seasonal adjustments of clothing can modify the thermal sensation with the environment. Newsham reviews the studies on thermal sensation of school children and concludes that small modifications in outfits insulating efficiency throughout the day can impact the thermal comfort. Modifications such as rolling up sleeves or opening buttons of the neckline can affect thermal comfort sensation. Therefore, not only major clothing adjustments for different seasons, but also minor modifications of the outfits can impact a student's thermal comfort condition.

2.6.2 Physical Activity Level

Heat generation in the body is a function of physical activity level. It is the least comprehensively explained aspect of all influencing aspects that has an impact on thermal sensation. Perhaps activity level is one of the most complicated factors that influence individuals' perception of thermal sensations and preferences since various parameters such as health condition and weight of individuals affect their metabolism and activity level (Charles, 2003; Goto et al, 2002).

Because measuring the activity level of each individual in the certain environment is very complex; researchers are generally applying the ASHRAE metabolic chart (Charles, 2003). According to ASHRAE/ANSI (2004) the metabolic rate (M) is an expression for measuring activity level. It is referred to conversion rate of 'chemical energy' into 'mechanical energy' and 'heat' via biochemical processes within a living organism. Met is a unit used to express the metabolic rate. (1met= 58 W/m2 (356 Btu/hr): Normal human being at relaxed seated position with the body surface area of 1.8 m^2 generates 58.2 W/ m^2 energy per unit surface area. Total heat generated by normal person is 104 W= 58 W/m^2 × 1.8 m^2). In the motionless or seated activities, the metabolic rate is within the small ranges (unremarkable differences) for individuals but for the rest of physical activities, the rate for a certain actions may have a considerable diverse range since it relies upon the task execution by an individual's (performance) and the conditions of the surrounding environment. As a person changes his/her activity level their metabolic rate fluctuates. Evaporation of sweat from the body surface turned into a particularly imperative aspect of thermal comfort as soon as metabolic rates rise further than 1 met. In ASHRAE Table many of the human activities are not verified and their metabolic rates are not estimated.

Bodily processes and body makeup can differ considerably for each individual. Physiological variations have an effect on thermal sensation. People with elevated metabolic rate or augmented body fat may feel warmer in hot environments compared to people with less body fat (Arens et al, 2001). Moreover, the chart is created for an average healthy adult, so the accuracy of the Table for children can be criticised. ASHRAE states that presented numbers do not hold sufficient facts and data about the children's thermal sensation but possibly the information in this set can be used for classroom situations.

Table 2.6: 'Metabolic Rates for Typical Tasks' (ASHRAE/ANSI, 2004)

Activity	Metabolic Rate met units	W/m^2	(BTU/h·ft
Resting			
Sleeping	0.7	40	(13)
Reclining	0.8	45	(15)
Seated, quiet	1.0	60	(18)
Standing, relaxed	1.2	70	(22)
Walking (on level surface)			
0.9 m/s, 3.2 km/h, 2.0 mph	2.0	115	(37)
1.2 m/s, 4.3 km/h, 2.7 mph	2.6	150	(48)
1.8 m/s, 6.8 km/h, 4.2 mph	3.8	220	(70)
Office Activities			
Seated, reading or writing	1.0	60	(18)
Typing	1.1	65	(20)
Filing, seated	1.2	70	(22)
Filing, standing	1.4	80	(26)
Walking about	1.7	100	(31)
Lifting/packing	2.1	120	(39)
Driving/Flying			
Automobile	1.0-2.0	60-115	(18-37)
Aircraft, routine	1.2	70	(22)
Aircraft, instrument landing	1.8	105	(33)
Aircraft, combat	2.4	140	(44)
Heavy vehicle	3.2	185	(59)
Miscellaneous Occupational Activities			
Cooking	1.6-2.0	95-115	(29-37)
House cleaning	2.0-3.4	115-200	(37-63)
Seated, heavy limb movement	2.2	130	(41)
Machine work			
sawing (table saw)	1.8	105	(33)
light (electrical industry)	2.0-2.4	115-140	(37-44)
heavy	4.0	235	(74)
Handling 50 kg (100 lb) bags	4.0	235	(74)
Pick and shovel work	4.0-4.8	235-280	(74-88)
Miscellaneous Leisure Activities			
Dancing, social	2.4-4.4	140-255	(44-81)
Calisthenics/exercise	3.0-4.0	175-235	(55-74)
Tennis, singles	3.6-4.0	210-270	(66-74)
Basketball	5.0-7.6	290-440	(92-140)

2.7 Environmental Factors

An individual's reaction to the thermal surroundings is coordinated and interconnected to various parameters, so the temperature of indoor air cannot solely verify thermal comfort (Levin, 1995).

Air temperature, humidity, radiant temperature, air velocity and humidity are all extremely important to create a satisfactory thermal environment.

2.7.1 Air Temperature

Air temperature refers to the temperature of the air surrounding the human body, so it determines the degree of the warmth or coldness in the atmosphere of the room. Air temperature is represented by T_a either in Fahrenheit (°F) degrees or Celsius (°C) degrees. However is not the only parameter affecting thermal sensation of the individuals, but it may be one of the most important factors affecting the thermal comfort condition. Indoor air temperature can directly influence evaporative and convective heat loss. In addition, it can ultimately influence conductive heat loss by affecting the surface temperature of items in a space (Heidorn, 1997).

Consistency or evenness of indoor air temperature is vital to generate a comfortable condition. Convection can cause problem called air stratification. It occurs when light hot air move to higher levels of the room and more intense cool air descend to the lower height of the room. If the ventilation means of the classrooms do not mix the indoor air appropriately, the degree of the temperature close to the top of the room can be much more (warmer) than near the ground. Furthermore, huge variation of indoor air temperatures can happen, if the temperature regulator (thermostats) has a broad temperature range in which no warming or chilling occurs (EPA, 2009).

Levin (1996) reviews the study on the thermal condition and occupant's productivity. He declares studies demonstrate that in the long-term an individual's work performance can decline 30% at 24°C compared to 20°C. Medium cold indoor air temperature can decrease occupant's sensitivity, manual speed and deftness by twenty percent. Moderately warm indoor temperature can decrease interpretation speed, logical-mathematical thinking, reading speed and writing. Occupants of a room with medium warm indoor air temperature are almost 30% less active in works which require mental activity compared to occupants of the place with thermally neutral environment. Jago and Tanner (1999) review some studies on the effect of temperature on school children. Studies demonstrates that unfavorable consequences such as increasing respiration rate, reducing physical exertion and increasing circumstances favorable to illness are caused by temperature above 23.9 °C. There are various researchers who confirm similar adverse effects of temperature on children. Wargocki and Wyon (2007) study verify that high indoor air temperatures in classrooms can reduce the school performance of 10 to 12 year old children. During the summer time, sufficient cooling have been provided for the testing classroom, the children performance on language-based task and mathematical assignment has been enhanced by decreasing moderately elevated indoor air temperatures from the 25 °C to 20 °C. The enhancement of student performance primarily is occurred in term of the speed of performance not the accuracy of students answering.

The classroom thermal environment can influence the learning capability of students. In general, student performance has a tendency to decrease in hot temperatures. A cold classroom can cause a decline in manual dexterity activities and speed of performance (Boxem and Zeiler, 2009). Therefore, enhancing the classroom thermal setting must be a vital educational precedence according to the characteristic of the task.

2.7.2 Radiant Temperature

Whether individuals are inside or outside of the building, they may sense the heat exchange by radiation. Even if the indoor air temperatures are in the comfort range, individuals can feel uncomfortable as they sit near a cold window on a cold cloudy day. Therefore, only consideration of air temperature can simply be ineffective to create thermally comfortable condition for occupants (Levin, 1995). Every object comparative to its temperature can release radiant energy at a certain degree, so individuals in the indoor space emit radiant heat to surrounding surfaces and surrounding objects also radiate heat to the surrounding environment (Heidorn, 1997). An individual body at resting condition can exchange around 50-60% of its sensible heat by radiation (Healthy Heating, 2009a). Each and every person in the room can emit radiant heat and affect each other (Heidorn, 1997). The radiant temperature is usually measured from radiant heat values (temperature degree) of the surrounding surfaces (e.g. walls) that are in positions to the body of individuals since they exchange heat by radiation (Atmaca et al, 2007). In the thermal comfort study of indoor spaces usually the mean radiant temperature (MRT: the average temperature of the indoor surfaces such as windows, walls and the ground) is used (Healthy Heating, 2009a,b).

Every human being consciously or unconsciously response to the sun's radiation as their body has experienced the effect of radiant heat exchange. Highly intense solar radiation can cause an unpleasant indoor thermal condition, since it amplifies the heat of the glazed surfaces inside the building. Consequently, it affects the MRT and eventually the condition of indoor thermal comfort. Moreover, if the sun's radiation directly penetrates on occupants, it aggravates discomfort sensation. A person in direct contact with the sun's radiation can feel a heat gain almost equal to an 11 °C increase in MRT (Hwang and Shu, 2011).

2.7.3 Humidity

Water vaporizes to the atmosphere as it is heated in the environment. The outcome of this process represents humidity which determines the concentration of water in the air. Relative humidity (RH) represents percentage of the humidity. It is described as ratio of the actual amount of moisture (water vapour) in the air and the upper limit (maximum) quantity of moisture that the air can contain. If the RH is within the range of 40% to 70%, it may not considerably impact thermal sensation. Indoor air moisture for the different indoor spaces may differ significantly. In the spaces such as a manufacturing room for paper or a laundry room, where drying processes take place high amounts of vapour are emitted, so they have an elevated humidity level in their environment. Even at high indoor temperature, individuals feel cold as they come out from swimming pool, or shower because amount of the water on the body surface can have a significant impact on sensation of thermal comfort.

Body evaporation cooling (evaporation of water from the individual's body surface) is reduced when humidity of indoor air rises (HSE, 2010; Levin, 1995). Sweat from the body surface (skin) is not able to vaporize as elevated level of humidity can prevent sweat evaporation. In warm indoor environments, an amount of moisture in the air is essential. When RH is above 80% smaller amounts of sweat can vaporize. The evaporation of the water from the body surface is the foremost means of heat loss for individuals. Environments with high humidity that contain masses of vapour in their atmosphere usually create an uncomfortable situation for its occupants (HSE, 2010).

According to Schneider (2002) the outcome of studies on thermal comfort determines that while RH and temperature level rise considerably, the students complain more about discomfort. In addition, their concentration level, performance and academic accomplishment decline. Students have a better performance in classrooms with RH in the range of 40% to 70% (moderate RH level) and indoor air temperature in the range of 68 °F to 74 °F (moderate indoor air temperature). They execute mental task most enhanced in classrooms that maintain temperature and humidity at moderate levels.

2.7.4 Air Velocity

Air velocity in the thermal comfort study is defined as the velocity of the air motioning across the occupant’s body. It is an essential affecting parameter in creating thermal comfort condition since individuals are sensitive and responsive to air movement. Air movement in a moist or hot indoor environment can raise convective heat loss with no modification in temperature of indoor air. When the temperature of the air is lower than temperature of the skin, it can considerably amplify heat loss via convection. Minor movements of air in cold environments may be recognized as draught. Occupants of the indoor spaces with motionless air that is unnaturally heated may feel stuffy. In addition, they may suffer from increase of unpleasant smell (HSE, 2010) since air movement can reduce the amount of body odour and pollutants from indoor environments.

In the indoor environments patterns of air movement are outcome of the various forces. Indoor air movement patterns are created by mixing of forces of occupant's activity, and ventilation systems (EPA, 2009). Therefore, not only natural or mechanical ventilation can affect air movement, but also occupant's physical activity may influence the air movement. Physical activity of the occupants may raise air movement, so occupants' level of physical activity should be considered to adjust proper air velocity for the indoor spaces. The function of a ventilation system is to enhance the highest supply of the fresh air to the indoor environment with the least loss of heated air or cooled air to the outdoor (Heidorn, 1997).

Few studies have been conducted about the relation of air velocity and the thermal condition of a classroom. Field studies on thermal conditions of a classroom for 10 to 12 years old students demonstrate that rising the supply rate of the fresh outdoor air from 3 to 9.5 L/s per person with moderate indoor temperate can progress the task performance of student. The outcome of the experiment demonstrate that increasing the rate of ventilation can enhance overall school academic performance and achievement by 8 to 14%, in addition it can decrease the temperature of ambiance air by 1°C degree (Technical University of Denmark, 2009).

According to Wargocki and Wyon (2007) study which is mentioned in air temperature part, students thermal sensation can transform from moderately hot to neutral if the outdoor air supply rate is amplified from 5.2 to 9.6 L/s per person. Student's performance on mathematical tasks has been improved considerably because of increasing in ventilation rate.

Children are probably more vulnerable to thermal circumstances of the environmental compared to adults. Adults are more flexible to unpleasant indoor circumstances, so in order to achieve their targets and meet the work deadline, they are usually able to conquer and handle many of the unenthusiastic effects of thermal conditions (Wargocki and Wyon, 2006)

2.8 Aim of the Study

This research aims to provide a better understanding of IAQ and thermal conditions and its impacts on students' health and comfort in Dubai elementary classrooms. It is envisaged that this will lead to the design of more comfortable study places for students and their teachers, in addition to the benefit of having more energy-conscious classroom.

2.9 Objective

- To examine IAQ and thermal conditions in Dubai's elementary schools' classrooms.
- To evaluate the influence of IAQ and thermal conditions on students' health and comfort in Dubai elementary schools' classrooms.
- To recommend appropriate strategies for improving the current indoor environmental conditions in Dubai elementary schools' air-conditioned classrooms.

Chapter 3: Methodology

3.1 Overview

This study demonstrates the relation between disclosure to air contaminants in classrooms and health problems and can evaluate the effectiveness of presented thermal condition of classrooms in relation to comfort level of students. Therefore, the measurement of indoor air contaminants and thermal condition in an elementary school ought to have a special consideration. Classrooms of four primary schools in Dubai were investigated between 6th to 18th of April 2011.

The methodology of this study is derived from reviewing the studies on thermal comfort and IAQ conditions of the indoor environment. Thus, the most common strategies and methods are used to measure the level of indoor pollutants and thermal conditions of the classroom. This research is intended as sequences of field study in classrooms while it is occupied by students. The following stages were used to accomplish the goals and objectives of this study.

- Walk-through Investigation
- Subjective study
- Objective Study (filed measurement)

3.2 Dubai Climate

Dubai has a hot desert climate with two seasons. It has a lengthy dry summer with temperatures as high as 48 °C. The summer time in Dubai is from May and to September. It has a short length winter, with moderate climate. The winter season runs from beginning of December to the end of March. During the winter temperatures rarely go below 6 °C. Usually

July is considered as the hottest month of the year and January the coolest. Humidity levels in the coastal areas are very high. Annual average of Relative Humidity (RH) may reach 60% in coastal districts; however, by moving to the inland district this rate reduces to 45%. The Average of RH is in the lowest during the May and during the winter months it usually reaches the highest level. The average of wind speed may reach 6 km/hr at 2m above earth level (United Arab Emirate Ministry of Environment and Water (UAE MOEW), 2010).

3.3 School Buildings and Their Sites

With the help of the educational department of British University in Dubai (BUID) the technical calls were made for the elementary schools for verification and approval. The investigation was carried out in six elementary schools in Dubai which were interested in taking part in this research. School buildings without published or reported IAQ and thermal condition difficulties were used for this study.

The required data were collected from air-conditioned classrooms of 4 elementary schools. The measurement was conducted for 2 classrooms in each school building, so 8 classrooms are considered for this study. The map below shows the district of each school. The pink colour determines the girl primary schools and the blue determines the boy primary schools. The schools are located in different regions of Dubai. Therefore, contradictory surrounding setting of each school may perhaps show the impact of school site on the IAQ of classrooms.

All selected school buildings are typical inner courtyard building, which is the most common traditional building type in the Middle East. The inner courtyard building is distinctive of Islamic structural design and is suitable for Dubai's climate. The selected schools are old style school building**s** with more or less modern architectural features (e.g. metal shade covering the main central courtyard). The main material used for construction of the selected schools is reinforced concrete or cement blocks.

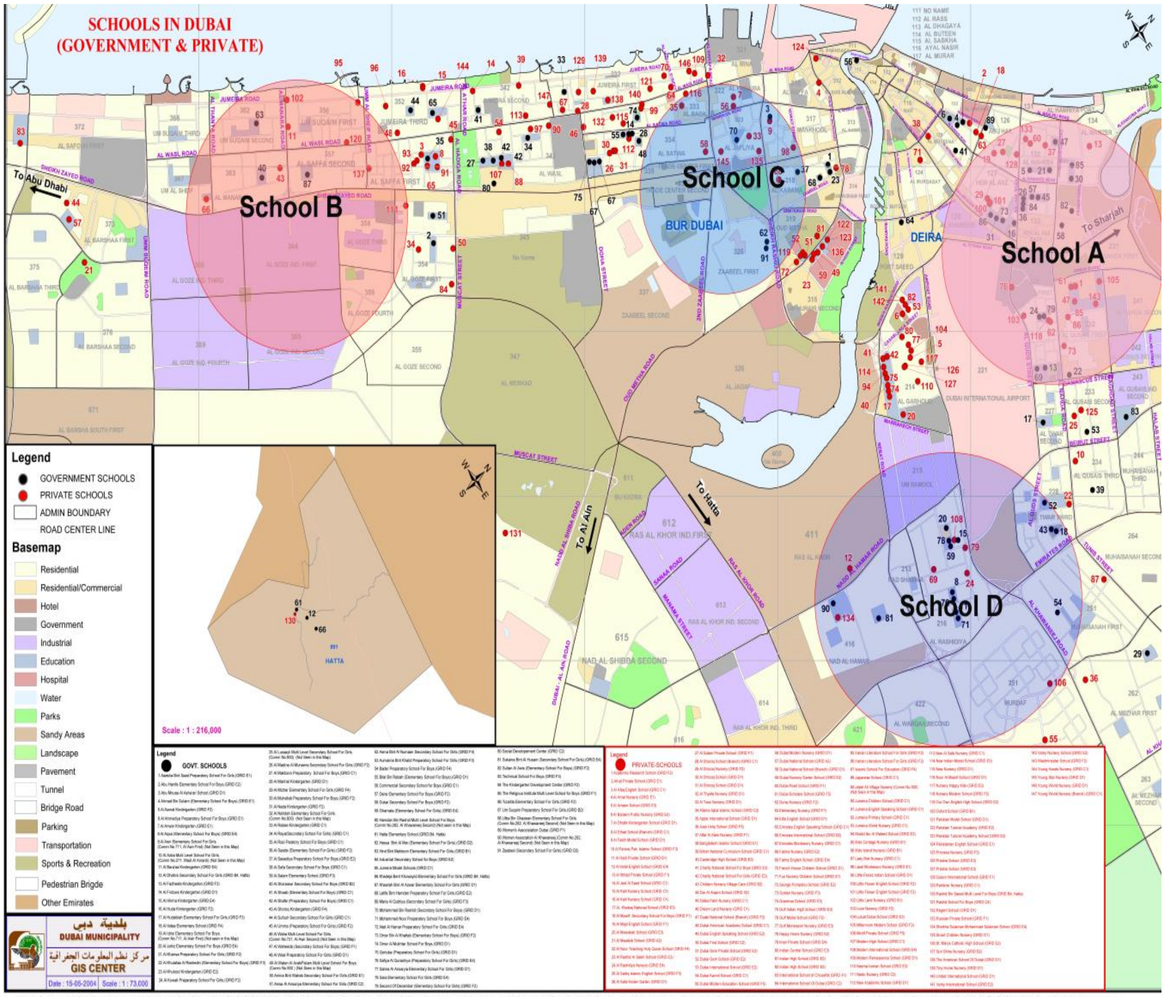


Figure 3.1: The districts of selected schools on Map of Dubai Schools (GIS CENTER, 2004)

3.3.1 School A

This is a public girl's school which provides education for girls aged between 6 to 12 years old (grade 1 to 5). Around 300 students are studying at this school. The school building is a two storey (ground floor and first floor) building and it has been used for more than 20 years as a girl primary school.

The school building is located in the highly populated area of Hor Al Anz. There are few public or governmental buildings close to the school building; in addition the school location is close to the Dubai International Airport. The class starts by 8:30 a.m. and finish by 2:15 p.m. The investigation of the first classroom (classroom A1) occurred on the 6th of April 2011 and investigation for the second classroom (classroom A2) occurred on the 7th of April 2011. Both of the studied classrooms were located in first floor.

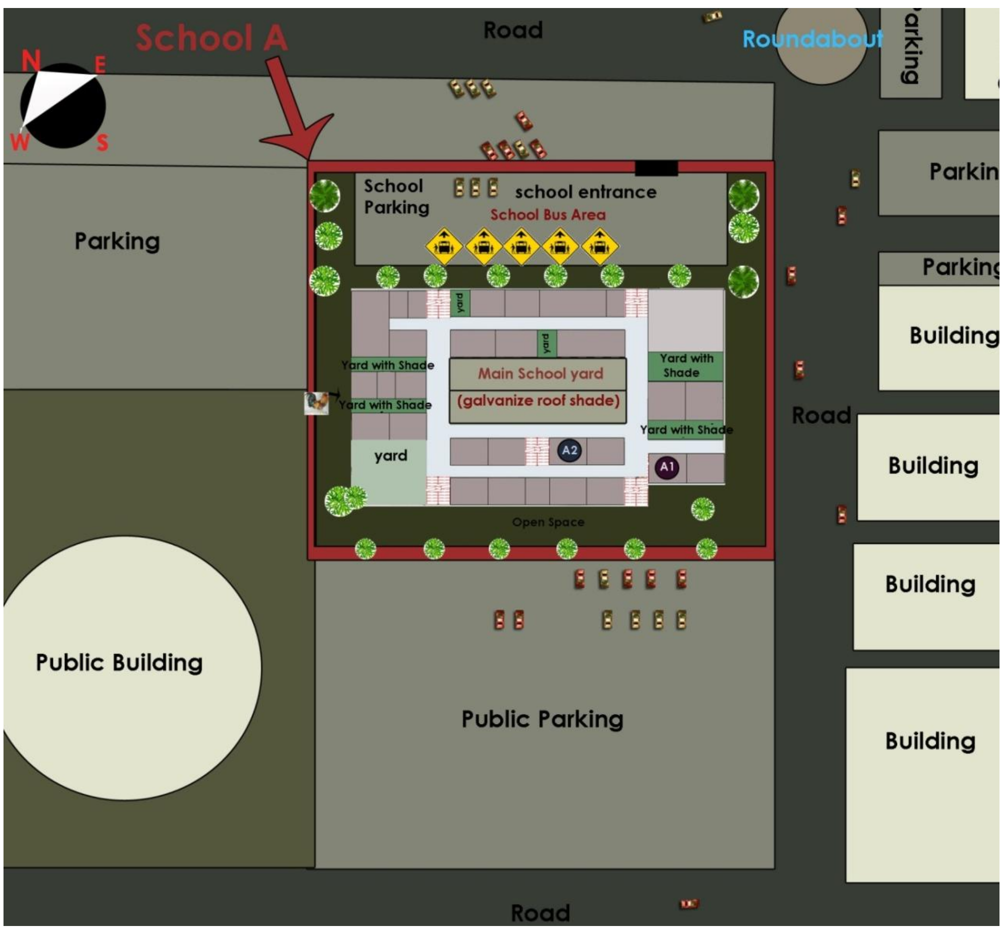


Figure 3.2: Site of School A

3.3.2 School B

School B is a public primary girl's school (like school A) which provides education for girls aged between 6 to 12 years old (grade 1 to 5). Around 400 students are studying at this school. The school building is two-storey (ground floor and first floor) and has been used for more than 20 years as a girl's primary school.

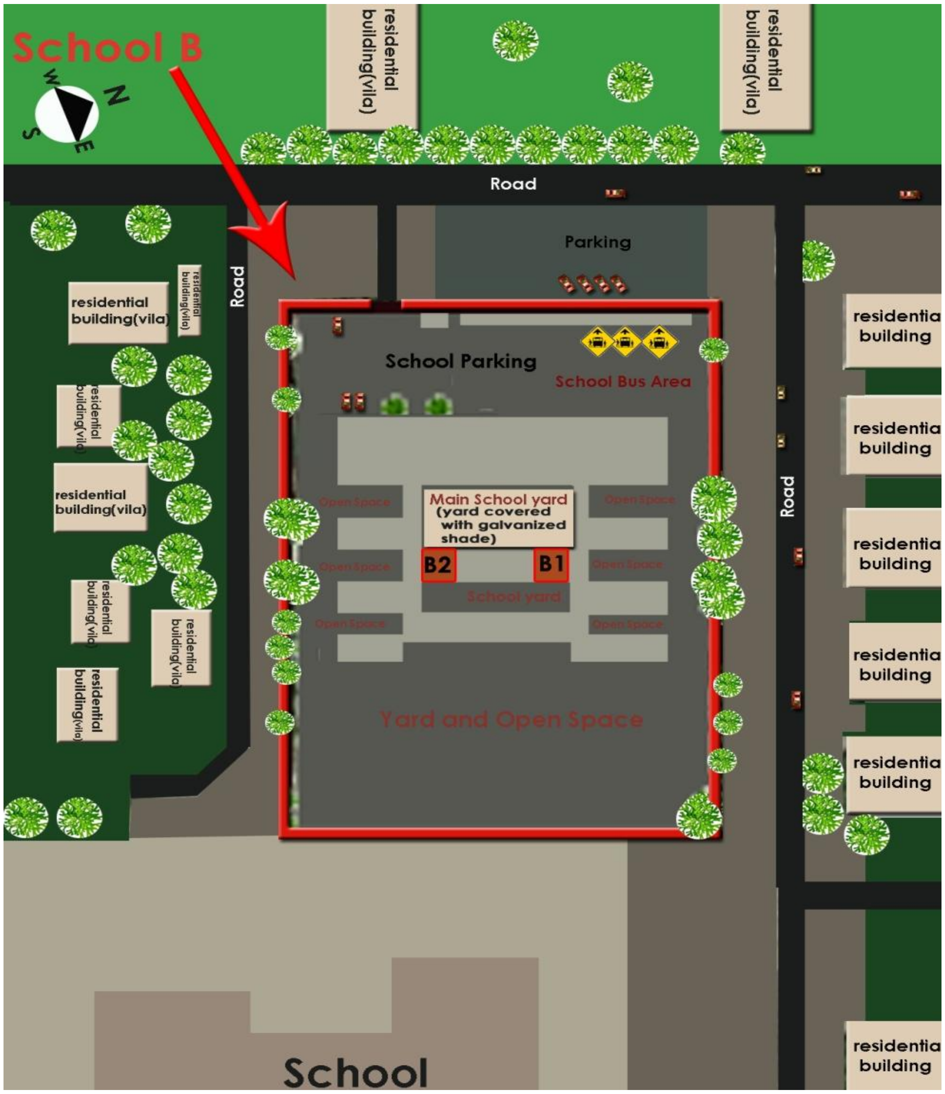


Figure 3.3: Site of School B

The School is located in the Um Suqeim area. It is one of the oldest schools in the Jumeirah district. There is another school south of School B building. Most of the buildings around the schools are residential villas. Compared to all selected schools, school B is closest to the seashore. The district around the school building has a green landscape because of the big villas in the area. The site of the building is not a very populated area (mostly villas) and does not have high traffic rate. The class starts by 8:30 a.m. and finishes by 2:00 p.m. Classrooms selected were located on the ground level. First classroom (classroom B1) was investigated on the 10^{th} of April 2011 and investigation for second classroom (classroom B2) occurred on the 11^{th} of April 2011.

3.3.3 School C

The school is located in the Al Satwa area. It is a public school that provides academic education for boys from the age of 6 to 10 years (Grade 1 to 5). Around 200 students are studying at this school. The school building is two-storey and it is approximately 7 years old. The school is cited in the highly populated area with the high traffic rate. There are two small mosques, one school and one big public parking area (chargeable) in the school district.

Both of the studied classrooms were located in the first floor. The class starts by 7:30 a.m. and finish by 1:15 p.m. The investigation of the first classroom (classroom C1) occurred on the 12^{th} of April 2011 and investigation for second classroom (classroom C2) occurred on the 13^{th} of April 2011.

Figure 3.4: Site of School C

3.3.4 School D

The school is located in the Al Satwa area. It is a public school that provides education for boys aged between 5 to 13 years (Grade 1 to 5). Around 280 students are studying at this school. The school building is two storeys and it has been used as boy's primary school for more than 20 years. The building is very close (around 500 metres) to the metro station and very close to Rashidiya Park. In front of the school building (North-West) there is library and small clinic and there is another school in east side of the school but majority of the buildings around the school are residential villas.

The class starts by 7:30 a.m. and finish by 1:15 p.m. The investigation of the first classroom (classroom D1) occurred on the 14th of April 2011 and investigation for second classroom (classroom D2) occurred on the 18th of April 2011. Both of the studied classrooms were located in first level.

Figure 3.5: Site of School D

3.4 Walk-through Investigation

The function of walk-through investigation is to become acquainted with the selected elementary school buildings in order to find any thermal or IAQ problems. This phase comprised of interviews and observations. An important step of this phase was a careful observation and visual evaluation of school building. Data and documents were gathered by observing interior, exterior, mechanical system and the contextual background of the building (Lee et al, 1996). In order to organize collected information, various Tables (checklists) are used. The required tools for this part of the study are as follow: camera, EPA school walk through check list (printed on paper), and a laptop (to organise the gathered information).

3.5 Subjective Study (Occupancy Survey)

Survey questionnaires were used for assessing the IAQ and thermal condition of classrooms. Questionnaires were adapted from AHRAE 55-2004 and 'Base Indoor Environmental Quality Survey' by EPA. The questions were modified to adapt to the local context. It focused mostly on the following parameters: physical and environmental condition of classroom, state of health and comfort of the occupants.

There were two sets of questionnaire**s**, one for the tutors and the other one for the students. The context of the teacher's and the student's questionnaires were similar; the only difference was that teacher's questionnaire had a few extra questions. The questionnaires were translated into Arabic as most of the participants were Emirati's and their first language is Arabic. In order to ease the concept of questions for kids; PowerPoint presentations with pictorial and child friendly design were provided. The presentation**s** contained questions in Arabic and English with some illustrations that helped the young students to understand the meaning of each question. The teachers also supported the students were necessary.

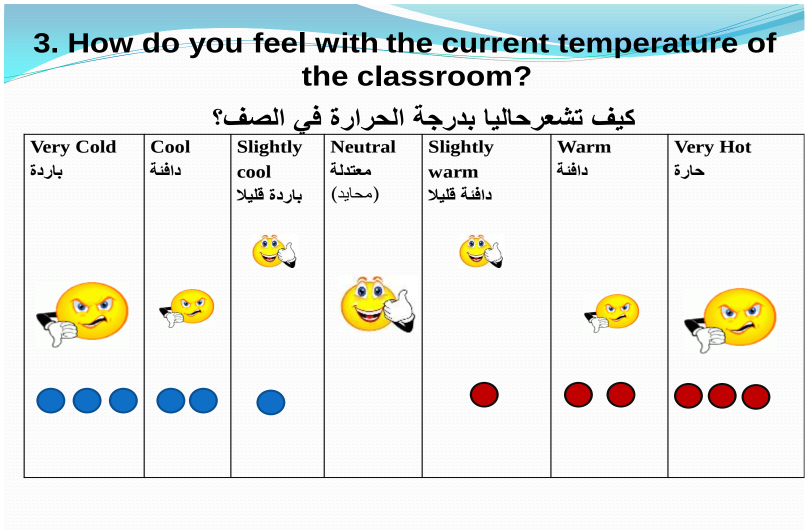


Figure 3.6: Example of one of the question in PowerPoint presentation

3.6 Objective Study (Filed Measurement with Mobile Devices)

In this part of the study the concentration of various indoor contaminants (chemical pollutants such as O_3, CO_2, CO, TVOCs and Total Particulate matters) and the degree of physical environmental factors (RH, temperature, and air velocity) of the classroom are measured by portable devices. Devices are located very close to the teacher's desk. Mobile devices are positioned in the classroom, in approximately 75 to 80 cm (30 inches) in height which is the approximate height of the child student's desk.

3.6.1 Portable Devices

Direct Sense IAQ (manufactured by Gray Wolf Sensing Solutions), consists of portable (hand held) monitoring devices. It is a highly accurate and very advanced portable IAQ monitoring system that can measure various indoor pollutants and physical parameters (Wolf Sense, 2009). Direct Sense IAQ consists of a Direct Sense Pocket PC (PPC), IQ-610 probe (measuring device with sensors), and AS-202A probe and PCC_10 Security Case.

PCC demonstrates measurements in real-time. It is connected to the probe device to document the IAQ parameters. The documented file can be easily transferred to computer (laptop) with the help of Wolf-Sense software and then into Microsoft Excel program.

Figure 3.7: PCC and it screen display (Wolf Sense, 2009).

The TIQ-610 probe has very fast response sensors that can measure indoor environmental pollutants such as Total Volatile Organic Compound (TVOC), Carbon Dioxide (CO_2), Carbon Monoxide (CO) and Ozone (O_3). In addition, the IQ-604 can concurrently measure physical environmental parameters such as relative humidity and temperature. During field measurements the IQ-610 probe as it is connected to the PCC was kept inside the PCC_10 Security Case for the safety reason**s**. The part of the probe which contain sensors was kept out of the case box (Figure 3.8 demonstrate**s** the situation).

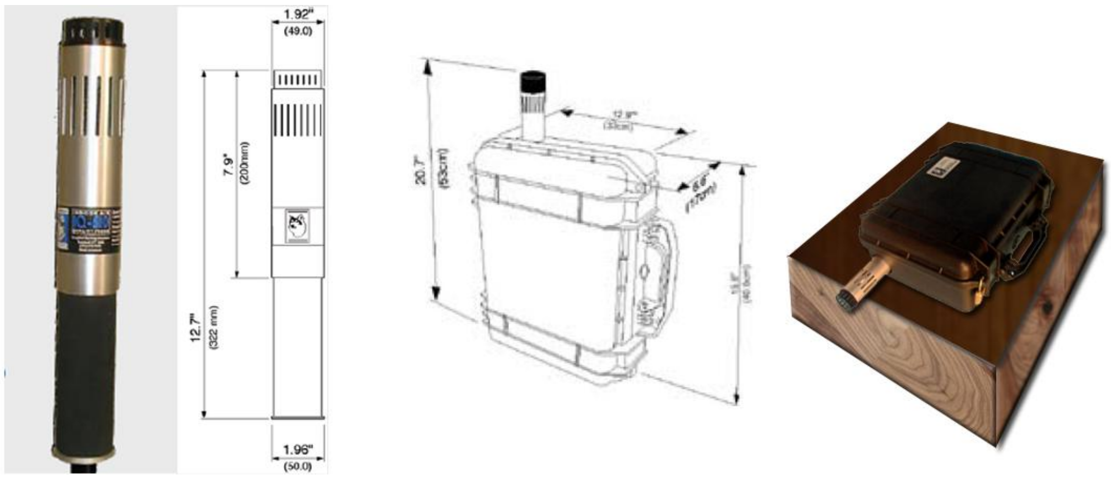


Figure 3.8: IQ-610 probe and PCC_10 Security Case with IQ-610 probe (Wolf Sense, 2009)

The PCC_10 Security Case which contains measuring devices was kept in each of the subjected classrooms for approximately 6 hours (from the beginning of the lesson to 30 minutes after students left the school). Measurement specifications of the IQ-610 probe are as follows: Detection range of VOCs is 0.02 to 20000 ppm. The device can detect CO between in ranges of 0- 500 ppm with the following accuracy: ± 2 ppm < 50 ppm, ±3%rdg >50ppm. The deivce can detect CO_2 in the range of 0 to 10000 ppm with the following accuracy: ±3%rdg ±50ppm. According to manufacturer the IQ-610 can measure the ozone range not less than (O_3) $\ll$ 0.01 ppm (10 ppb).

AS-202A probe is an air velocity measuring device. It is a 'telescoping device with 90º articulating tip and laser etched in centimetre (cm) and inches scale' (Wolf Sense, 2009). The probe was connected to PCC while it was used for measuring airflow rate at the supply air diffusers. The machine was used after students left the school for approximately 10 minutes.

Figure 3.9: AS-202A probe (Wolf Sense, 2009)

GrayWolf Sensing Solutions Company which is manufacturer of Direct Sense IAQ suggested two approving devices that can highly accurately measure Total Particulate Matter (TPM) and Formaldehyde. RK-FP30 is suggested for measuring the concentration of HCHO and Thermo Scientific pDR-1500 PM-205 for total concentration of PM (Wolf Sense, 2009).

RK-FP30 or HCHO detector is used for measuring indoor formaldehyde concentrations. Detection range of the device is 0-1.0 ppm and accuracy of the device is ± 010 % (RKI Instruments, 2011). It takes 30 minutes (1800 seconds) for the device to measure the Formaldehyde concentration. After 30 minutes the measured value displays on the LCD of the device. The device was used for last 30 minutes of school lesson. The measuring with this device was started around 1:45 p.m. for the girls' schools and 12:40 p.m. for the boys' schools.

The results of RK-FP30 measurement were manually written. The device was located on the desk (75 to 80 cm in height) next to the desk that IQ-610 probe and Thermo Scientific PDR-1500 were located.

Figure 3.10: RK-FP30 (RKI Instruments, 2011)

Thermo Scientific pDR-1500 (made by Thermo Fisher Scientific Company) is a portable instrument that can measure total concentrations of particulate matters. The minimum measurable concentration for this device is 0.001 mg/m^3 and maximum is 400 mg/m^3. Particle size range that can be detected by the device is between 0.1 to 10 μm. The flow low rate range of the device is around 2 litres per minute. 'Precision (repeatability over 30 days) of the device is ± 0.2 % of reading or ± 0.005 mg/m^3, whichever is larger for 60 seconds averaging time. Accuracy of the device is ± 0.5 % of reading' (Wolf Sense, 2008). The documented measurement by the device can be easily transferred into the PC with the help of the Thermo

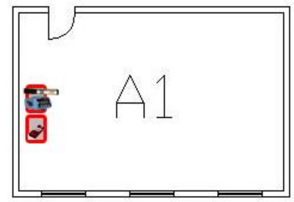
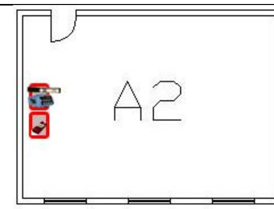
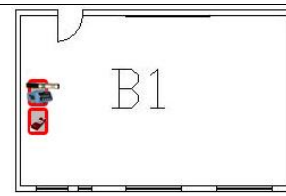
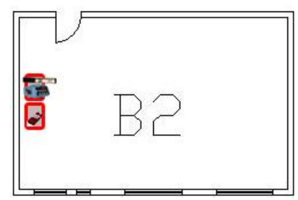
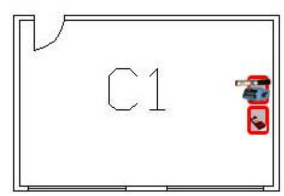
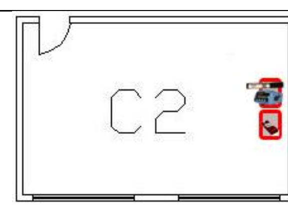
Scientific software and specific connection wire. The software can draw the graph (diagram) of PM concentration with respect to time.

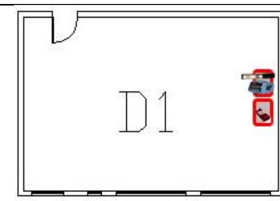
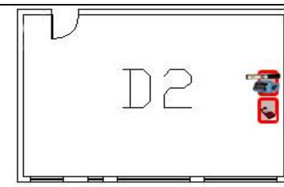
Figure 3.11: Thermo Scientific pDR-1500 (Thermo Scientific, 2011)

The device was used alongside with the IQ-610 probe of Direct Sense. It was placed on top of the PCC_10 Security Case. The machine measured the total concentration of PMs for approximately 6 hours.

The following Table demonstrates the running time of measuring devices in each classroom. In addition, it demonstrates the approximate place that devices were positioned for each classroom.

Table 3.1: Running time of Measuring Devices and their installed location for Each Classroom

Name of the Classroom	Running time for IQ-610 probe	Running time for RK-FP30	Running time for the DR-1500	The place that devices were posited
A1 **(6/April/2011)**	**8:05 AM to 14:15 PM**	**13:45 PM to 14:15 PM**	**8:28 AM to 14:34 PM**	
A2 **(7/April/2011)**	**8:30 AM to 14:20 PM**	**13:45 PM to 14:15 PM**	**8:19 AM to 14:12 PM**	
B1 **(10/April/2011)**	**8:41 AM to 14:31 PM**	**13:45 PM to 14:15 PM**	**8:30 AM to 14:26 PM**	
B2 **(11/April/2011)**	**8:35 AM to 14:25 PM**	**13:45 PM to 14:15 PM**	**8:25 AM to 14:21 PM**	
C1 **(12/April/2011)**	**8:11 AM to 14:11 PM**	**12:40 PM to 13:10 PM**	**7:49 AM to 14:04 PM**	
C2 **(13/April/2011)**	**7:53 AM to 13:43 PM**	**12:40 PM to 13:10 PM**	**7:43 AM to 13:43 PM**	

D1 (14/April/2011)	**8:29 AM to 12:39 PM 12:44 PM to 14:34 PM**	**12:40 PM to 13:10 PM**	**8:04 AM to 14:25 PM**	
D2 (18/April/2011)	**8:02 AM to 14:02 PM**	**12:40 PM to 13:10 PM**	**7:51 AM to 13:45 PM**	

3.7 Limitation of the Study

There were various limitations that needed to be addressed concerning the present study. Limitation of the study must be addressed in order to evaluate this study and enhance future investigation.

1. Students and some teachers cannot speak English (Second language English). Communicating with students was hard due to language barrier. Few of teachers can speak English fluently, others were not able to entirely assist the researcher and explain question to students. Thus, it must be better if an Arabic speaker carried out the next study.

2. More time was required. Study was performed during one climate, further analysis during the winter months would help make more informative evaluations.

3. Very disruptive students (due to the age) and they have difficulty in understanding the questions. Generally students who participated in the study were very young and their level

of knowledge about indoor environment and health was very limited. One of the main concerns of this study was analysing thermal comfort conditions in classrooms, but this goal may not be fully achieved since some questions which impact thermal comfort analysis must be eliminated (removed from the questionnaire in appendixes because of the biased answers) since occupants (mainly students) had difficulty in answering them. Probably different age group (secondary, cycle two) would be more appropriate age group for future studies on children.

4. Many schools were initially approached but only four came forward to welcome the investigation (with the help of KHDA). Only four schools out of over 500 primary schools were investigated.

5. The focus of this study is on children and the environment that they study in. The questionnaires are more suitable for Grade 4 or Grade 5 students, but since the students of these grades are not spending majority of their school time in a specific room, this research investigates the thermal condition and indoor air quality condition of Grade 3 classrooms and their students.

6. The questionnaire was designed with pictorial illustrations to explain the questions and ease the meaning of the questionnaire. Teachers helped in explaining each question to the students, but some of the students did not take the survey questionnaire seriously and some of them could not understand the meaning or concept of some of the questions. Moreover, dealing with kids and explaining the concept of the research proved to be very hard.

7. However, all principals and some of the teachers are very helpful and interested in participating, but unfortunately not all the teachers or staff of the schools could speak English, so there was a communication problem explaining the whole concept of the study for them.

8. The first step was a walk through investigation. This is preliminary (fundamental) conversation with the facility and operating managers of school building, but unfortunately interviewing them was not possible. Since they were not in the school and getting in touch with them was not possible. In addition, they could not speak English properly.

9. People working in the cleaning department in the schools could not speak English at all; therefore, they cannot actually participate in the study.

10. Architectural and mechanical drawings of the schools' buildings were not available for most of the schools. They could have eased assessments and comparisons between actual design and thermal and IAQ settings of school buildings.

11. However, the best measuring result could be achieved if the devices were located in the middle of the classroom, but the centre area could have had an impact on the learning quality of the children (by distracting them). Also, putting the devices in the centre of the classroom may adversely impact the teachers' comfort, since they cannot control misbehaving students. In order to control difficult behaviour, it is suggested to put measuring devices close to teacher's desk. If devices are close to where the students sit, they may harm the devices because of their curiosity. Moreover, it was not possible to position the measuring devices in the same spot in all selected classrooms due to the location of the electricity layout (location of electric plugs) in the classrooms. As a health and safety precaution, a plug extension was not used.

12. Turning on the devices at the precise identical time was not possible due to the slowness of devices to log data and due to lack of assistance.

13. In some of the classes teachers are absent or they left the classroom, so this had an impact in controlling the remaining students.

Chapter 4: Results

4.1 Walk -through investigation

The results of the staff interviews and the walk through observation are briefly described for the selected classrooms for each school. Areas of concern or observable problems that impact indoor air quality of each school have been described. The results can be useful for identifying the critical components that affect the IAQ. In terms of indoor material and furniture most of the selected classrooms had a very similar interior furnishing and material. The majority of selected classrooms had a similar type of student desk and chairs which were made of plastic (polypropylene) and steel. The majority of the teacher's desks were made of pressed wood. Teacher's chairs were a regular revolving chair made of fabric, steel and plastic. All selected classroom had painted finished walls and ceilings. In addition, all of them had ceramic tile flooring. Since the majority of the indoor furniture and materials are more than 6 months old, they may not impact the level of indoor VOCs in all selected classrooms. Only in school A recently (3 months) carpets have been put in both selected classrooms. Consequently low level of microbiological problems or VOCs and high level of particulate matters can be anticipated.

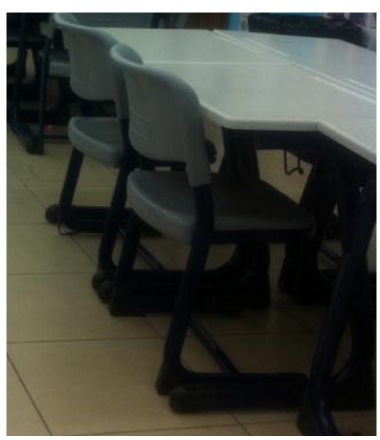


Figure 4.1: Student's Desk and Chair

4.1.1 Walk Through of School A

Cleaning of the rooms happened sharply after students left the school around 2:30 p.m. The air conditioning system maintenance occurred every 3 months. The building and the facilities were in good shape. Renovation and painting took place during September before the start of the fall semester. The storage room for cleaning materials and solvents was located far from the classrooms.

Only five observable problems were identified for school A. Firstly, some of the toilet surfaces in the first floor had mould problems due to water leakage and humidity. The mould problem in toilets may impact the health condition of sensitive students. Secondly, interior surfaces of some rooms on the first floor were covered with dust (particles).

Thirdly, a rooster and some other birds lived in a cage in one of the small yards located in the south west which may cause an allergy problem for some of the students. Fourthly, both of the classrooms have small carpet in front of the classroom close to the white board, since students sit on the carpet for some special lessons. The carpet may impact the level of particulate matter since it holds contaminants and soil from students' and tutors' shoes. Finally, both of the selected classrooms are probably affected by the pollution of the public parking areas since there is a short distance to public parking. The IAQ of one of the classrooms (A1) may be more influenced by pollution produced in the public parking since the windows can be open directly toward public parking (almost 15 meters distance). Wall units AC (wall or window unit AC) are located on top of the windows and their exhaust ducts are towards the parking.

Classroom A1: The room volume is around 162 m^3 (height ≈3m, width ≈ 6m and length ≈ 9m). The furniture layout of the classroom had no adverse impact on the ventilation system since the layout does not block any intake passage of the air-conditioning system. The ventilation system of the classroom consists of a split unit air conditioning system, 3 ceiling fans and 3 window units. The windows are always closed. The door is the only means of natural ventilation. During the investigation only the split unit air conditioning system was used as a cooling system. Fans and window unit mechanical systems were not in use (turned off) during the investigation.

Figure 4.2: Furniture layout in classroom A1

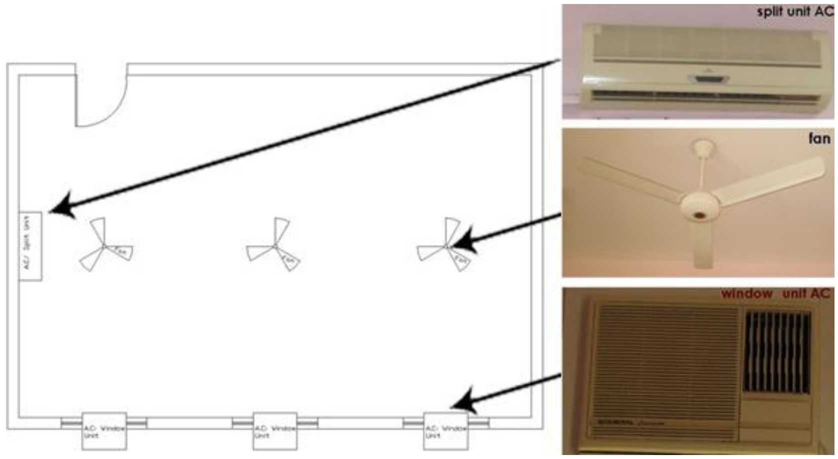


Figure 4.3: Ventilation plan of classroom A1

Classroom A2: The room volume was around 175.5 m^3 (height ≈3m, Width ≈ 6.5m, length ≈ 9m). However, the number of the tables and chairs were different for classroom A1 and A2, but the information about classroom A2 was very similar to classroom A1. The only difference was that classroom A2 was slightly bigger than classroom A1. In addition, there was some different between the layout of the furniture in the classrooms.

Figure 4.4: Furniture layout in classroom A2

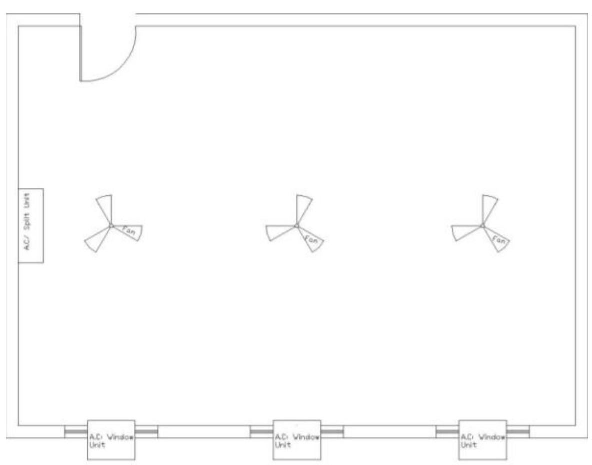


Figure 4.5: Ventilation plan of classroom A2

4.1.2 Walk through of School B

The building and the facilities were in a fine condition. Renovation and painting usually took place during September before the start of the fall semester. Proper maintenance of the air conditioning system occurred yearly at the same time as renovation and painting practice. Cleaning of the rooms happened after the students left the school around 2:30 p.m. The cleaning products and solvents were located in a small storage room under the stairs which was 20 metres from the classrooms. Only 3 observable problems were identified for school B. Firstly, dusts on the surface of some furniture or art and crafts within the classrooms. Secondly, the amount of VOC was probably very high in the classrooms of school B because of the usage of air freshener products to reduce the amount of undesirable odour (mostly body odour). Thirdly, the external part of the window AC system was covered with dust and trash; therefore, the performance of the mechanical system may be affected due to the presence of the dust.

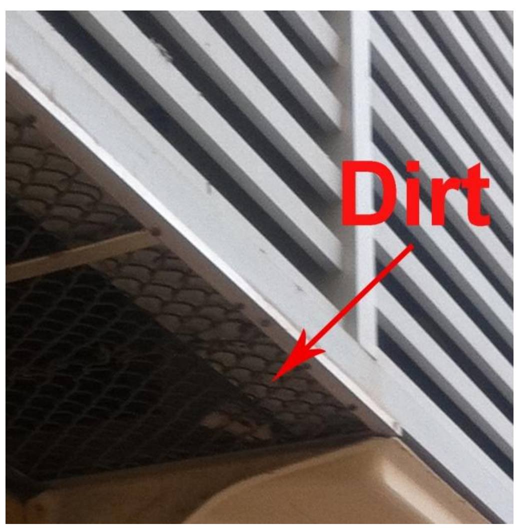


Figure 4.6: The outdoor part of Window Unit

Classroom B1: The room volume was around 171 m^3 (height ≈3m, Width ≈ 6m and length ≈ 9.5m). The investigation occurred on the 10th of April 2011. Generally the furniture layout of classroom has no unfavourable impact on the ventilation system, but some suspended hand-made arts and crafts that are created for learning proposes may impact the quality of the indoor air since they may act as a particle sink by collecting dust. The collected dust may be suspended into the air, whenever the fan was on. The ventilation system of the classroom consisted of 6 ceiling fan, and two window AC units. In addition, teachers mentioned that the fans were turned off most of the time. Only during the hottest period of academic year (end of May to end of June) they were used to ventilate the room. During the investigation it was observed that the door was the only means of natural ventilation. During the investigation fans are turned off and windows are closed; therefore, only the window AC system was used as a cooling system, and this was a usual practice. Windows are only used as means of natural ventilation during the cold season.

Figure 4.7: Furniture layout of classroom B1

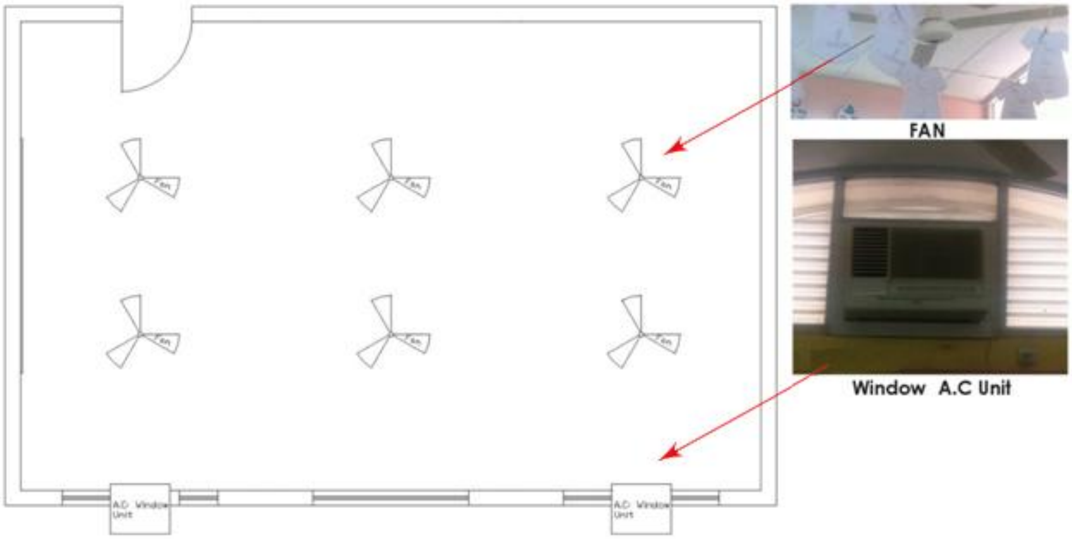


Figure 4.8: Ventilation plan of classroom B1

Classroom B2: The room volume was around 171 m^3 (height ≈3m, Width ≈ 6m and length ≈ 9.5m). The investigation occurred on the 11th of April 2011. The information about classroom B2 was very similar to classroom B1.

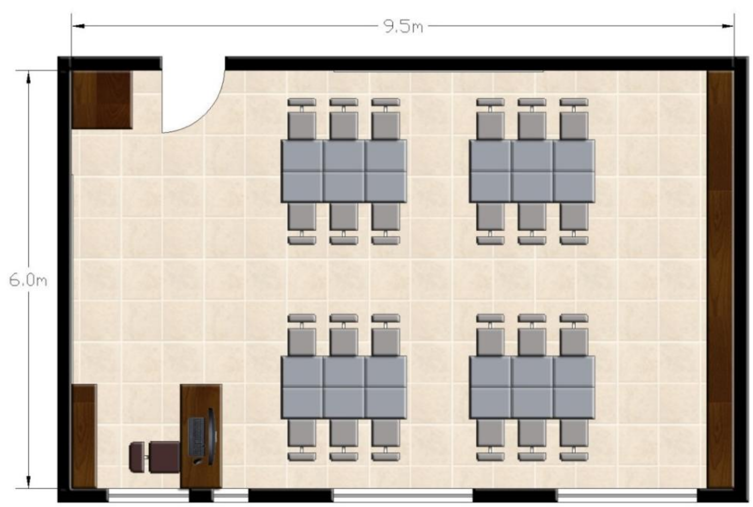


Figure 4.9: Furniture layout of classroom B2

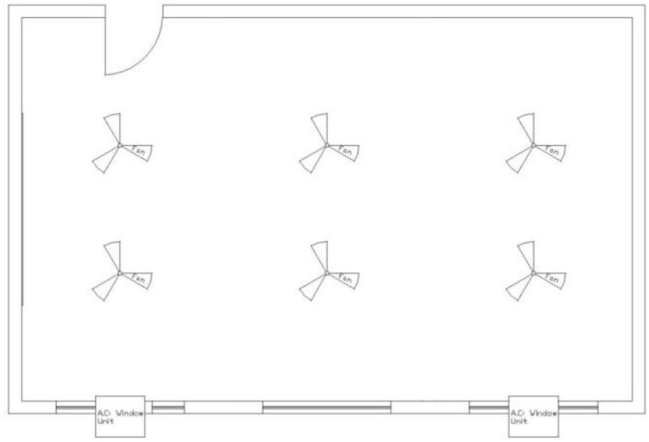


Figure 4.10: Ventilation plan of classroom B2

4.1.3 Walk through of School C

The building and the facilities were in very good condition. Similar to all the other schools, renovation and painting usually took place during September before the start of fall semester. Thorough maintenance of the air conditioning system occurred monthly. The classrooms were cleaned prior to the students arrival (6 a.m.) and their departure at (1.30 p.m.). Cleaning products and solvents are located in a small storage room in the cafeteria and also in the kitchen. All the selected schools had dust on all vertical or horizontal surfaces, but school B did not have such a problem (as the rooms were cleaned twice daily). Due to the morning cleaning, the amount of TVOCs in this school may be higher than others. In addition, the cleaning products which were kept in an unventilated storage room in cafeteria may impact the health of the student’s.

Carpets were used for some teaching and learning. The students sat on the carpet with their shoes on. The carpet used in the room could have been the source of indoor contaminants. Carpets are usually the source of particles since they hold the dust and particles.

Classroom C1: The room volume was around 140 m^3 (height ≈3m, Width ≈ 5.5m and length ≈ 8.5m). The investigation occurred on the 12th of April 2011. The school is located in a very populated area with a high traffic rate. In addition, the school is very close to the major road. Many trucks and SUV's usually parked near the South West wall of the school that was very close to classroom C1 and C2. Furthermore, there was public parking (metered) very close to the school building. Therefore, the amounts of chemical pollutants may be very high. The ventilation system of the classroom consisted of 2 ceiling fans, and 3 split units (mechanical system). The windows were closed during the investigation. Windows are never open as means of natural ventilation due to safety reasons.

Like all the other schools, the door was the only means of natural ventilation. During the investigation only the split unit AC system was used as a cooling system. All other ventilation machineries (fans) were turned off during the investigation.

Figure 4.11: Furniture layout of classroom C1

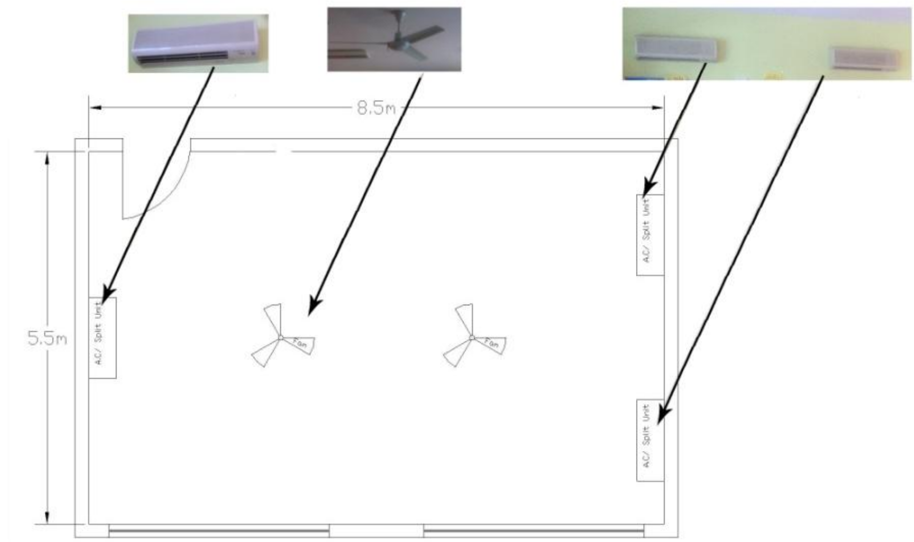


Figure 4.12: Ventilation plan of classroom C1

Classroom C2: The room volume was around 140 m^3 (height ≈3m, Width ≈ 5.5m and length ≈ 8.5m). The investigation occurred on 13th of April 2011. The information about classroom C2 was very similar to classroom C1.

Figure 4.13: Furniture layout of classroom C2

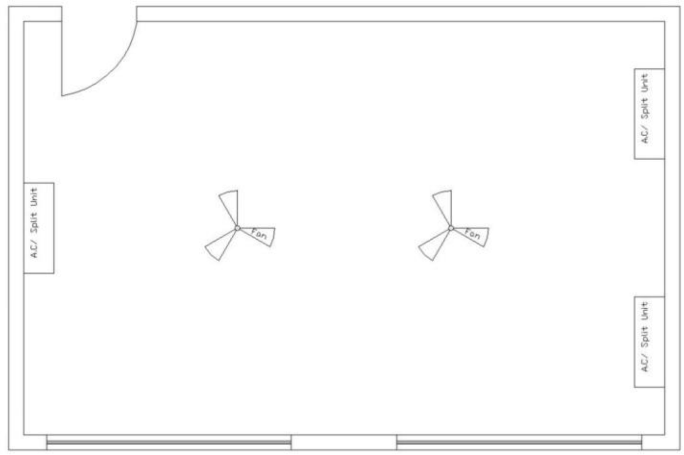


Figure 4.14: Ventilation plan of classroom C2

4.1.4. Walk through of School D

The building and the facilities were in a good state. Renovation and painting occurred at similar times to all other studied schools. Proper maintenance of air conditioning system occurred twice a year. Cleaning of the rooms happened when there was no student in the school (around 2:00 pm) Cleaning products and solvents are located in a small storage that had no ventilation system, but was away from the classrooms.

The school's location was very close to the motorway and the airport, but also close to the park and many residential villas that had green landscape. Possibly the outdoor air in the site of the school contained high amounts of chemical pollutants due to fossil fuel used for airplane and cars. The parking area for the school bus was very close to the classroom area (which included classroom's D1 and D2). The distance between the school bus areas to some classrooms was less than 30 metres which is the recommended distance. Therefore, the exhaust gas coming from the buses would probably impact the ventilation system (air conditioning system) of the classrooms. In addition, a school bus was observed idling between 11:45a.m., and 1:15p.m.

Figure 4.15: Idling of School Buses in School D

Carpets in some of the classrooms such as D2 probably contained large amounts of dust and particles. The existence of dust was observable on the vertical or horizontal surfaces in the classrooms.

Classroom D1: The investigation occurred on the 14th of April 2011. The ventilation system of classroom consisted of 6 ceiling fans, and 2 split unit AC systems. Like school C, windows are never open during the school hours. Like all other schools, the door was the only means of natural ventilation and only the split unit AC systems are used as a cooling system during the investigation. All of the fans are turned off during the investigation, but according to teachers they were not a good source of ventilation since they held particles on their surfaces and while they are turned on they could potentially spread high amounts of particles in the room.

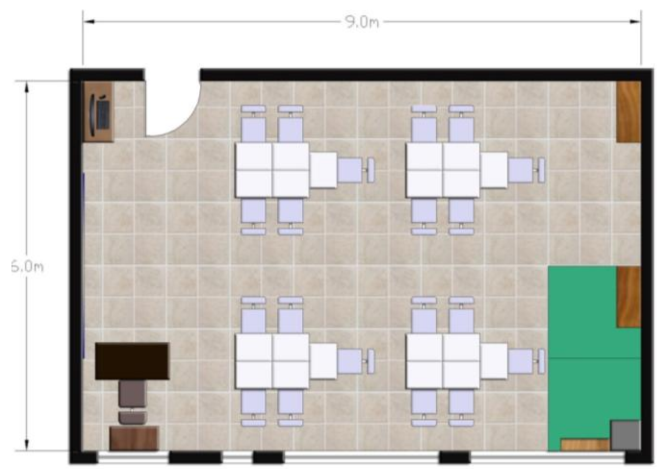


Figure 4.16: Furniture layout of classroom D1

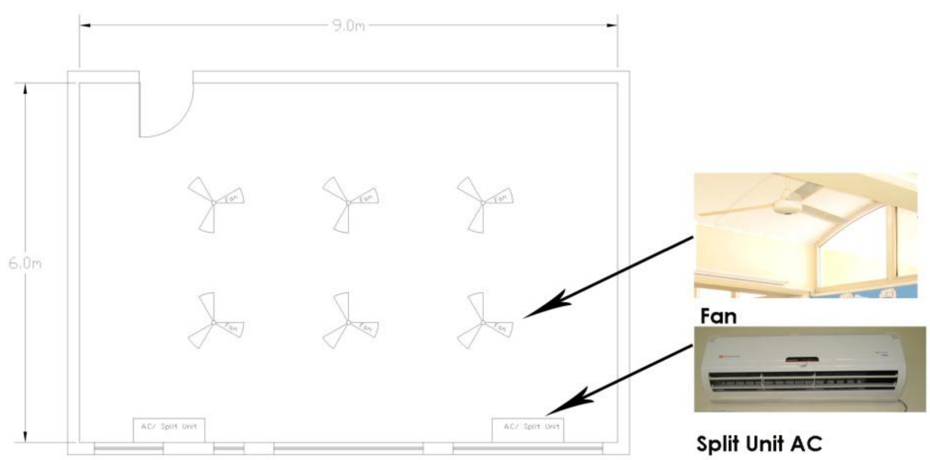


Figure 4.17: Ventilation plan of classroom D1

Classroom D2: The investigation for this room occurred on 18th of April instead of 17th because students were on a field trip on 17th of April. Between all subject classrooms, it was the only classroom with hard wood furniture. The layout of the furniture and shape of the furniture created a very friendly atmosphere for students, but at the same time created a very tight personal space for them since they sat very close to each other.

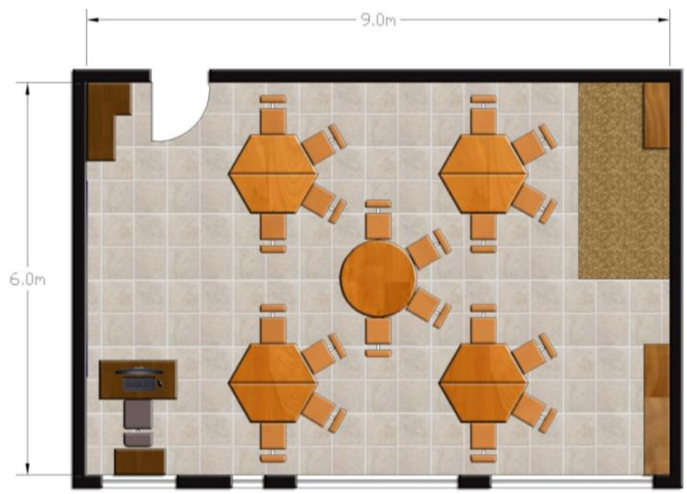


Figure 4.18: Furniture layout of classroom D2

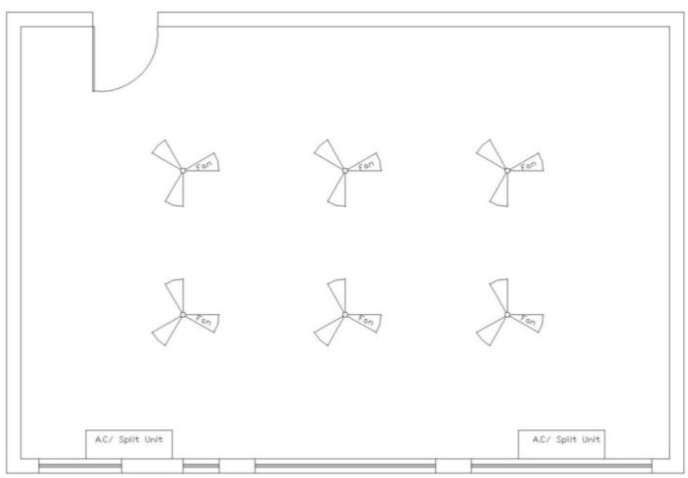


Figure 4.19: Plan of classroom D2

4.1 Objective Study

Classrooms indoor temperatures and RHs and their relation to time are shown in graphs. In addition concentrations of air pollutants for each of the studied classrooms are also shown in graphs. Graphs of air pollutants demonstrate the peak concentration of each contaminant.

Some general pieces of information that must be pointed out before evaluating the monitoring data are: firstly, because the teacher of classroom A1 was not present on the measuring date, students left the room earlier than usual, however, another teacher had been teaching students of classroom A1 for some time. Students had not used the room for most of the monitoring time and this is not a usual practice. Their absence impacted pollutant concentrations of indoor air, thus, measured values are not typical indoor values of pollutants. Secondly, the concentration of formaldehyde for all the measured classrooms was less than 0.01 (HCHO: 0<0.01). Thus, this value is not mentioned in the related section for each classroom. Low concentration value of HCHO probably occurs because no new furnishing had been used in the selected class rooms.

4.2.1 Classroom A1

The investigation occurred on the 6th of April 2011. The average outdoor temperature was 33 °C. The average outdoor humidity was 19 %. The average outdoor wind speed was 14 km/h (Weather Underground, 2011).

Results of the indoor air temperature and relative humidity (physical indoor parameters) are shown in figure 4.20. The associated graph determines that values of indoor RH are in descending order, while the values of the indoor temperature are in ascending order. Maximum indoor RH was 35.9 % at 8:05 am and the minimum was 14.8 % at 2:15 pm. Maximum temperature was 28.5 °C at 2:15 pm, and minimum was 24 °C at 8:05 am. According to the Dubai climatic condition, the outdoor temperature increases from morning to afternoon because of the sun's heat. Climate has a major impact on building performance and it affects the indoor temperature. During the morning time that the outdoor weather is cooler, so the indoor temperature is at a minimum level. The results show that during the time that the door of the class is closed, the value of relative humidity dropped. For example, at 8:25 am as the class started, the value of relative humidity dropped. The average of RH was 26.6% and the average of indoor temperature was 27 °C. The average of the indoor air speed was 3.7 m/s at 15 cm from the diffuser and 2 meters above the floor. The air conditioning system roughly creates the constant air speed.

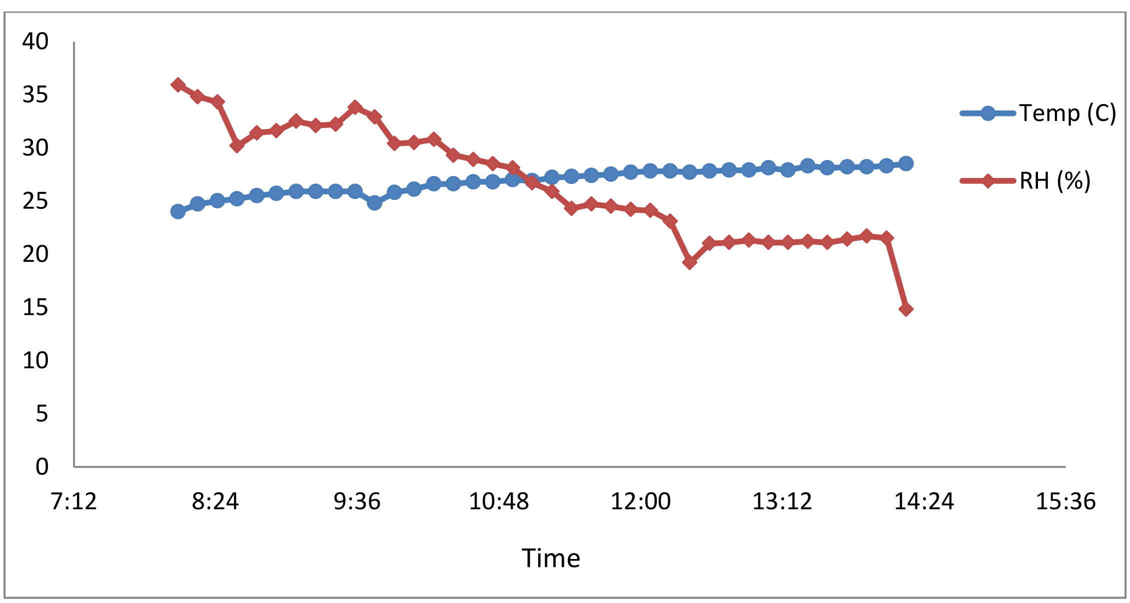


Figure 4.20: Temperature and Relative Humidity of Classroom A1

Figure 4.21 demonstrates concentrations of TVOC, CO_2, and O3 over 6 hours. The minimum concentration of TVOCs was 57 ppb at 8:05 am while there were only a few students (5 to 7) inside the classroom. The maximum concentration of TVOCs was 585 ppb at 9:35 am, when the classroom is full. This number demonstrates that the level of TVOCs is dependent on the number of students in the classroom. Human bodies release very low levels of VOCs through the skin; therefore very small portions of TVOCs are created by occupants. Students and teachers personal stuff that are made of synthetic materials (odorous chemical) such as notebook, markers, rubber, glue, bag, pencil case, shoes etc sometimes can have a critical impact on the concentration of TVOCs. Moreover, the public parking area which is close to the classroom started getting full around 9:30 am since office work usually starts at 10:00 am. The increasing pattern of RH at 9:36 am can be related to the peak level of TVOCs, since the classroom door had been opened for a few seconds.

The highest value of CO_2 occurred (9:35 am) while classroom had been occupied for more than an hour. In addition, at that time activity level of occupants was high and the carbon production rate was higher than usual. The metabolic rate increased at 9:35 am since students participated in a special lecture for which they walked across the class to sit on carpet. By 9:45 am students left the classroom. When the classroom was almost empty the concentration values of carbon dioxide and TVOCs started decreasing. The classroom was empty between 9:45 am to 12:14 pm, but between 11:25 and 11:35 am the door of the classroom was slightly open since a few students came to the classroom for few minutes. The classroom was full again between 12:14 to 12:45 pm. After 12:45 pm the classroom was almost empty for the rest of the measurement period. Therefore, indoor concentration of CO_2 showed a decreasing pattern. The indoor concentration of CO_2 reached a steady state between 13:20 pm and the indoor value had happened to be very close to the outdoor level. Between 13:20 to14:15 pm the door of the classroom had been opened twice for few seconds (e.g. at 14:10 pm students came back to pick up their belongings) but indoor level of carbon dioxide slightly fluctuated around 660 ppm.

The maximum concentration of O_3 was 60 ppb at 1:55 pm when the sun's radiation was high (sun was on a sharp angle) therefore, complex photo-chemical combination of NO_x and VOCs generated by vehicles caused the acceleration of ozone production. The concentration of O_3 might be associated with idling school buses or the vicinity of the classrooms to the public parking or the closeness of school to the airport. The minimum concentration of O_3 was 20 ppb between 8:05 to 8:15 am. The indoor concentration of ozone was probably correlated to the outdoor concentration. The classroom door was usually opened at 8:00 am and the air conditioning system was turned on by 8:30 am. The door was locked for more than 15 hours (from the previous day) and the AC was turned off for more than 17 hours. Therefore, ventilation systems (mechanical or natural) were not used for a while and outdoor ozone had not entered the room.

The maximum concentration of CO was 2400 ppb occurring at 9:45 and 10:15 am when the public parking was very crowded and the classroom was full. The minimum concentration of CO was 1800 ppm at various points in time. The average concentration of TVOCs, $O_{3,}$ CO and CO_2 were 368 ppb, 42 ppb, 1958 ppb and 863 ppm respectively.

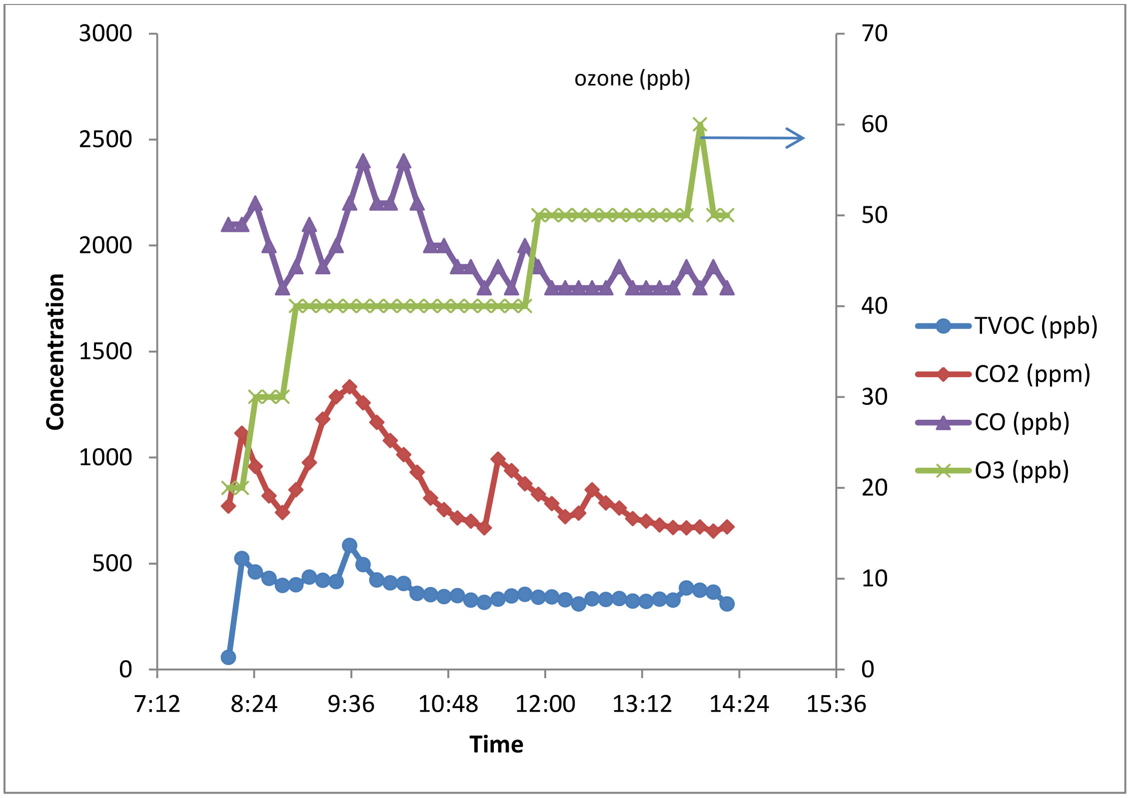


Figure 4.21: Concentrations of TVOCS, CO2, O3, and CO in classroom A1.

Figure 4.22 displays the concentrations of total particulate matters (TPM) during 6 hours. The minimum concentration of TPM was 146.47 µg/ m^3 at 8:19 am, when the classroom door was closed and dusty outdoor air did not enter the room. As the ventilation systems started to work, the increasing pattern between 8:30 am and 9:30 am was observed. Dust was seen floating in the air as the air conditioning system was turned on. The air conditioning system influenced the level of TPM by re-suspending the particle and dust. Figure 4.22 demonstrates sudden increase of TPM concentration around 9:35 am when students walked across the classroom and sat on the carpet. In addition, at the time the door was slightly pen for few seconds and outdoor air which contained high level of particle entered the room. The carpet in the classroom affected the concentration level of TPM. The carpet was a great source of particles, since hazardous particles and dust (even dust mite and biological contaminants) can sink down deeply into the carpet fibres. The greatest value of TPM was 265.58 µg/ m^3 at 10:21 am. The outdoor activity probably which caused the creation of particles taking place around 10:21 am. The exhaust gases from vehicles (fossil fuel vehicles) are known for producing ultrafine particles; thus, the public parking could be source of the particulate matters. It was mentioned before that between 9:30 am, and 10:00 am there were so many cars in the public parking area, as a result TPM concentration level reaches its peak at 10:21 am. During the rush hour or traffic time whenever the classroom door was opened the indoor concentration of TPM suddenly increased. The average of TPM was 183 µg/ m^3.

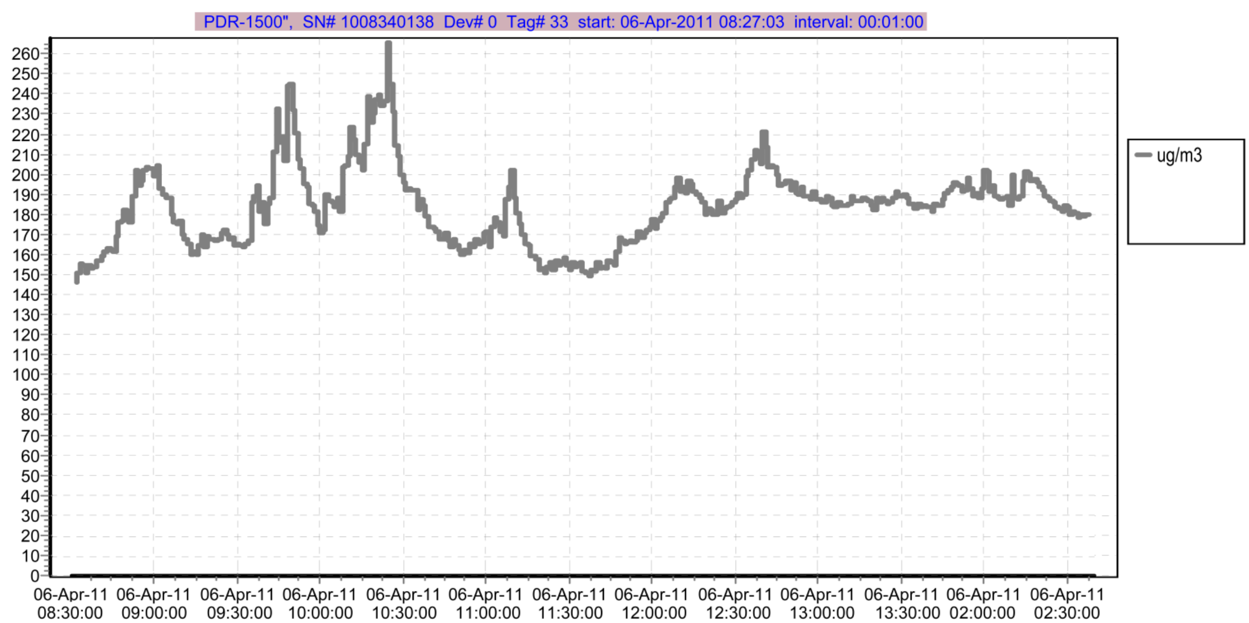


Figure 4.22: Total PM Concentrations, Indoor temperatures, and RHs of Classroom A1

The Table 4.1 demonstrates the average value of physical parameters and measured the indoor air contaminates of classroom A1.

Table 4.1: Average of physical parameters and indoor contaminants

Measured component in Classroom A1	**Average**
Air Speed	3.7 m/s
Relative Humidity	26.6%
Indoor Temperature	27 °C
TVOCs	368 ppb
CO_2	863 ppm
O_3	42 ppb
CO	1958 ppb
TPM	183 µg/ m^3

4.2.2 Classroom A2

The investigation occurred on the 7th of April 2011. The average outdoor temperature was 33 °C. The average outdoor humidity was 19 %. The average outdoor wind speed was 16 km/h (Weather underground, 2011).

Figure 4.23 represents results of the indoor air temperature and the relative humidity. Values of the indoor temperature were in ascending order in a very similar manner as outdoor temperature. Between 8:30 am. and 8:50 am the outdoor temperature was around 23 °C. Consequently, the minimum indoor temperature was 22.5 °C at 9:00 am. Individuals' bodies generate heat by movement of the muscles; thus, between 8:30 am and 8:50 am when students are not very dynamic the quantity of the heat generated by students was very low. Subsequently, the indoor temperature reached its minimum due to conditions created by mechanical system and the fact that the door of the classroom was fully closed. The door of the classroom was fully open between 13:05 p.m. and 14:20 p.m. The highest value of indoor temperature was 26.7°C when the outdoor temperature was very high. The maximum temperature occurs at 14: 10 pm.

Maximum indoor RH was 30 % at 9:00 am when the classroom door was closed and mechanical system was the only means of ventilation. The minimum value for RH was 16.8 % at 14:20 pm when the door of the classroom was opened. The average of RH was 26.6% and average of indoor temperature was 25 °C. Both of studied classrooms of school A had the same indoor air speed. Average of the indoor air speed was 3.7 m/s very similar to classroom A1. Generally outdoor temperature and humidity had a major impact on indoor value of humidity and temperature in classroom A1 and A2.

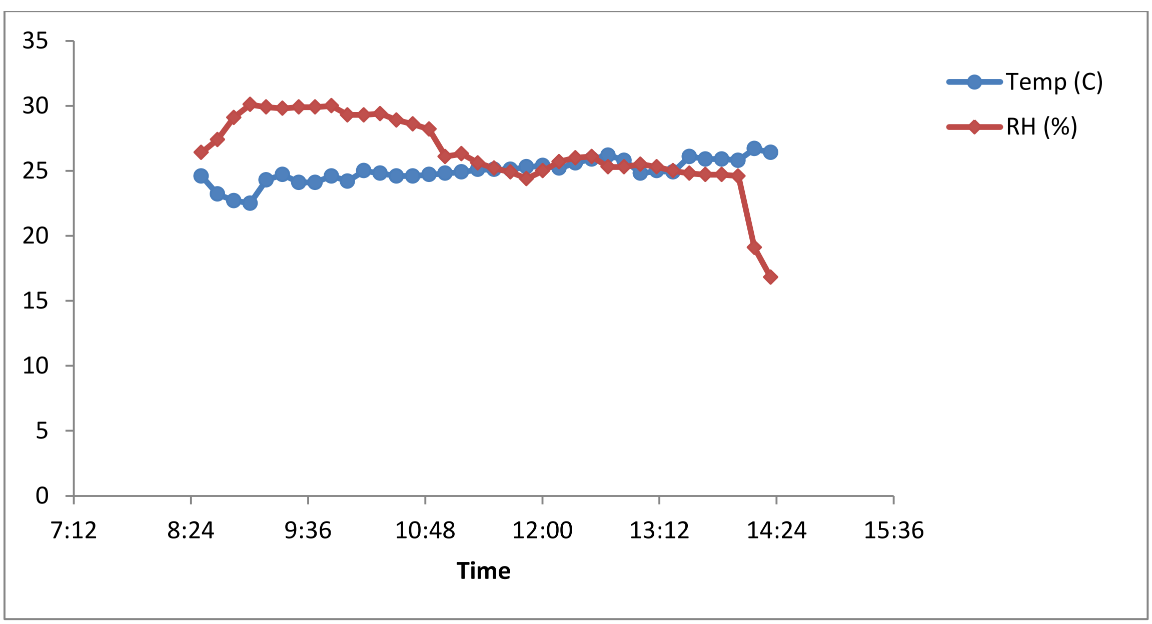


Figure 4.23: Temperature and Relative Humidity of Classroom A2

Figure 4.24 illustrates concentrations of TVOC, CO_2, and O_3 for 6 hours. The minimum concentration of TVOCs was 19 ppb at 8:30 am when the classroom was empty. The door of the classroom was closed. Therefore, the outdoor TVOCs did not impact the indoor level of TVOCs significantly. Moreover, there were no occupants in the classroom to increase the level of TVOCs. The maximum concentration of TVOCs was 730 ppb at 9:20 am, when the classroom was full. The highest TVOCs value in classroom A1 occurred around the same the time (9:35 am), so probably the outdoor concentration of TVOCs was high and ventilation means of the classroom brought the contaminant into the indoor environment. Between 9:15 am and 9:25 am the door of the classroom was slightly open and the indoor concentration reached its utmost. At this time, students were close to the measuring devices; therefore, their belongings probably released VOCs and had an impact on the concentration value of TVOCs. Between 12:20 pm and 12:30 pm the door of the classroom was fully opened and the indoor concentration level of TVOCs reached 729 ppm. Thus, the outdoor level of TVOCs had a major effect on the indoor level. Like TVOCs the minimum concentration of CO_2 occurs at 8:30 am. The lowest level of CO_2 (629 ppm) occurred before the start of lesson (class room had been empty since the day before). At 10:10 am the concentration value of indoor CO_2 reaches the maximum value which was 1590 ppm. At 9:20 am students were very active. They jumped on to the carpet and played a game with their teacher, so their level of generated CO_2 rose. Between 9:10 am and 10:10 am concentration values of CO_2 had an increasing pattern. From 10:20 am and 12:00 pm the classroom door was slightly open and no one was in the classroom, hence concentration values of carbon dioxide had a descending order. At 12:00 pm more than 30 students were actively participating in the class lecture which was very dynamic. Thus, carbon dioxide production range increased.

Between 8:30 am and 10:00 am the concentration of the ozone stayed constantly at 40 ppb which was the lowest concentration of ozone for classroom A2. The maximum concentration of O_3 was 60 ppb at 1:50 pm and 14:20 pm, when the door of the classroom was open; consequently the outdoor level of ozone which is higher than indoor could easily influence the indoor level. The minimum concentration of CO was 900 ppb at 9:00 am when the external air was not entering the room by means of natural ventilation since the door was closed. The maximum concentration of CO was 2000 ppb at 10:20 am. The classroom door was slightly open at that time, so increasing rate for indoor carbon monoxide was caused by outdoor level of carbon monoxide. The average concentration of TVOCs, $O_{3,}$ CO and CO_2 were 408 ppb, 48 ppb, 1968 ppb, 1438 ppb, and 1238 ppm respectively.

Figure 4.25 presents the concentrations of total particulate matters (TPM) for 6 hours. The minimum concentration of TPM was 103 µg/ m^3 at 12:00 pm when no one was in the room. At 12:00 pm the classroom became full with occupants. Around 32 (students plus one teacher) people were in the room and 10 of them were sitting on the carpet. Concentration levels of TPM started to amplify. Between 12:00 pm and 12:35 pm as the students sat on the carpet, an increasing pattern was observed. In addition during that time the door was opened and contaminated outdoor air came into in the classroom. The highest indoor level of TPM was 268 µg/ m^3 at 12:35 am. The outdoor air probably was contributed to indoor level of TPM. In general values of TPM for selected classrooms (A1, and A2) were elevated. High indoor concentration of TPM was probably due to the old age of the school, existence of carpets and the polluted outdoor air in the site of the school.

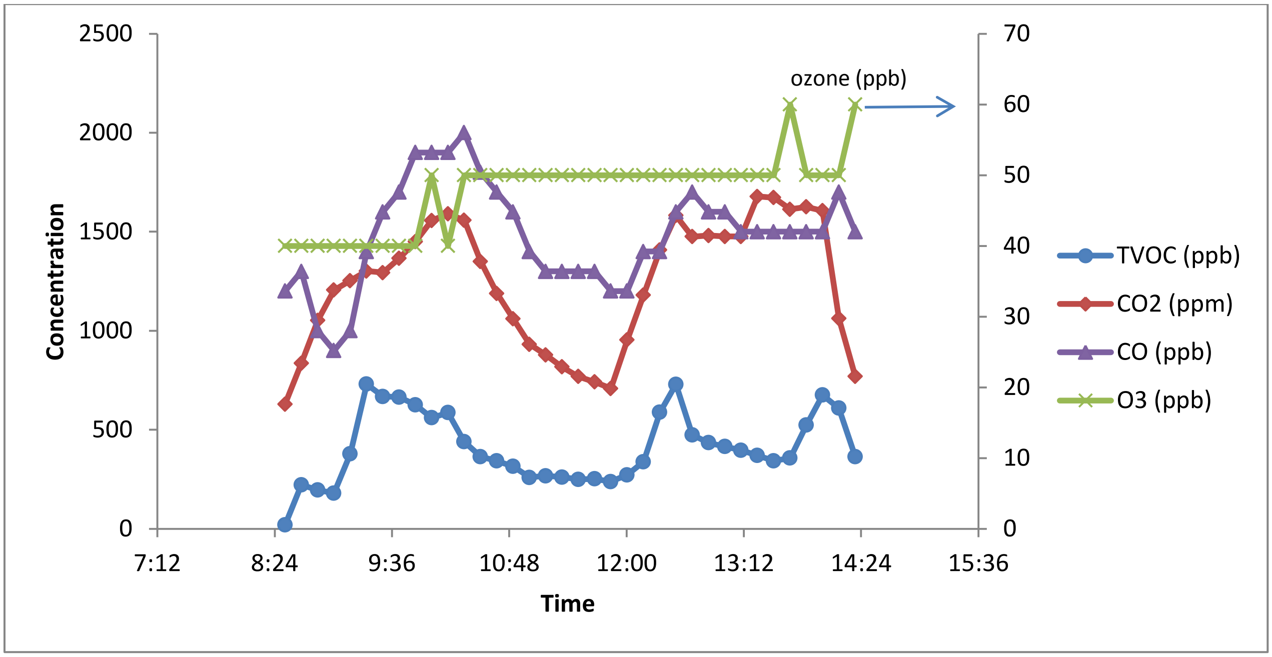


Figure 4.24: Concentrations of TVOCS, CO_2, O_3, and CO in classroom A2.

Figure 4.25: TPM Concentrations in Classroom A2

The Table 4.2 demonstrates the average value of physical parameters and measured indoor air contaminates of classroom A2.

Table 4.2: Average of physical parameters and indoor contaminants

Measured component in Classroom A2	**Average**
Air Speed	3.7 m/s
Relative Humidity	26.6 %
Indoor Temperature	25 °C
TVOCs	408 ppb
CO_2	1238 ppm
O_3	48 ppb
CO	1968 ppb
TPMs	160 µg/ m^3

4.2.3 Classroom B1

The investigation occurred on the 10th of April 2011. The average outdoor temperature was 29 °C. The average outdoor humidity was 48 %. The average outdoor wind speed was 14 km/h (Weather underground, 2011).

Figure 4.26 represent the values of temperature and relative humidity in classroom B1. Maximum indoor RH was 49 % at 2:30 pm when the classroom was empty of students and the door of the classroom has been kept closed for long period of time. The minimum relative humidity was 34% at 11:41 am. The minimum temperature was 24 °C at 8:41 am. In the morning the outdoor weather was cooler because of the rain the night before. The indoor temperature rose as the outdoor temperature increased because of the low insulation value of the wall. The maximum temperature was 26°C between 14:21 pm and 14:31 pm. The mechanical ventilation system that was located at front of the classroom generated an average air speed of 7.3 m/s at 15 cm from the diffuser and was 2 meters above the floor. The mechanical ventilation system at the back of the classroom produced average wind speed of 2.2 m/s. The average of RH, temperature and indoor air speed were 40%, 25 °C, and 4.75 m/s.

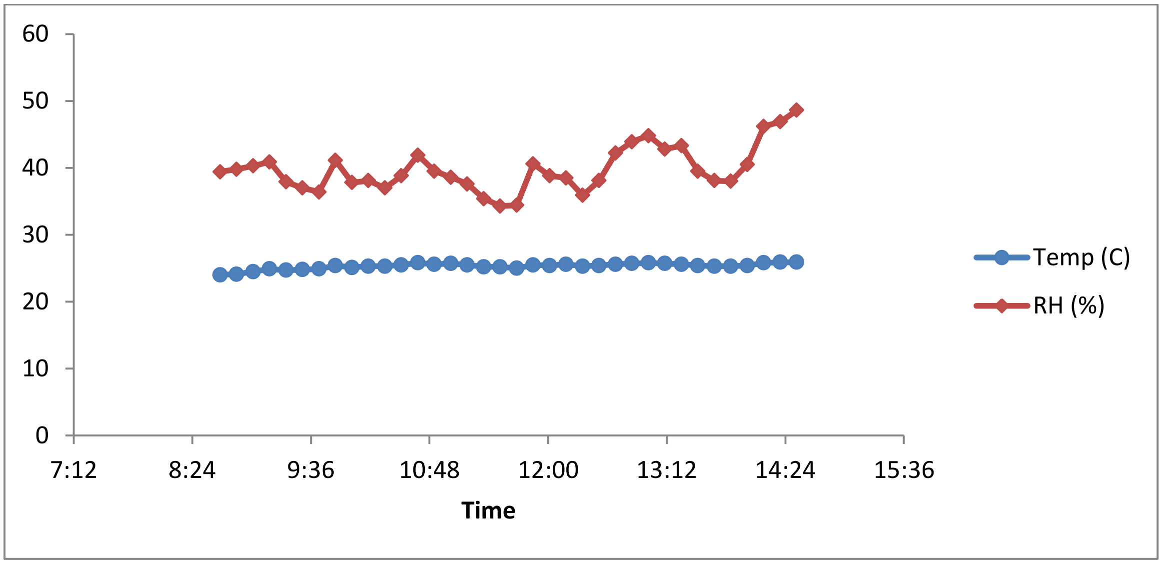


Figure 4.26: Indoor Temperature and Relative Humidity of Classroom B1

Figure 4.27 displays 6 hours indoor concentration values of CO, TVOCs, O_3, and CO_2. In the morning the smell of cleaning products is normal. Air-freshener products are used to create a pleasant smelling environment. Between 8:45 am and 9:40 am the classroom door had been closed for the majority of the time, only once the door had been opened slightly for a few seconds. At the beginning of the measuring period, the maximum concentration of TVOCs occurred. The highest value for TVOCs is 520 ppb was at 8:41 am. The minimum concentration of TVOCs was 213 ppb at 14:31 pm when the classroom door was closed and the outdoor air which contained a high concentration of VOCs could not greatly impact the indoor TVOCs level.

In addition, students had not been in the room for a while, so their belongings which were made of synthetic materials (that can release VOCs) could not affect the environment of the room.

The maximum concentration of CO_2 was 1527 ppm at 9:41 am while the students were very active. The indoor concentration of carbon dioxide declined as the students left the classroom at 12:35 pm and at 13:11 pm it reached the minimum level which was 604 ppm. The minimum concentration of O_3 was 40 ppb at 8:41 am. The maximum concentration of O_3, which was 60 ppb occurred at various time between 10:31 and 14:31. According to the figure 4.26, indoor concentration of ozone increased mostly when the quantity of TVOCs decreased. Thus, there might be a correlation between concentration level of ozone and TVOCs, which needs further investigation. The maximum concentration of CO was 1900 ppb between 8:41 am and 8:51 am. The highest concentration of carbon monoxide took place at the beginning of the school lesson. Very close to the time that school buses were leaving the parking area. School B was located in an area full of residential villas with green landscape, so the school buses could have been the main reason for concentration level of indoor pollutant such as VOCs and CO. Therefore, the distance between buses and classroom must be increased. In addition, the idling time of buses must be reduced. The minimum concentration of CO was 1000 ppb at 11:21 am when the classroom door was closed and no one was in the room. The classroom had been empty for some time and the door of the classroom had been kept closed. Although outdoor air did not affect the room around 11:21 am, the outdoor activities which promote CO production were limited (no school bus, low number of vehicle). The average concentration of TVOCs, $O_{3,}$ CO and CO_2 were 293 ppb, 54 ppb, 1333 ppb and 1013 ppm respectively is 293 ppb.

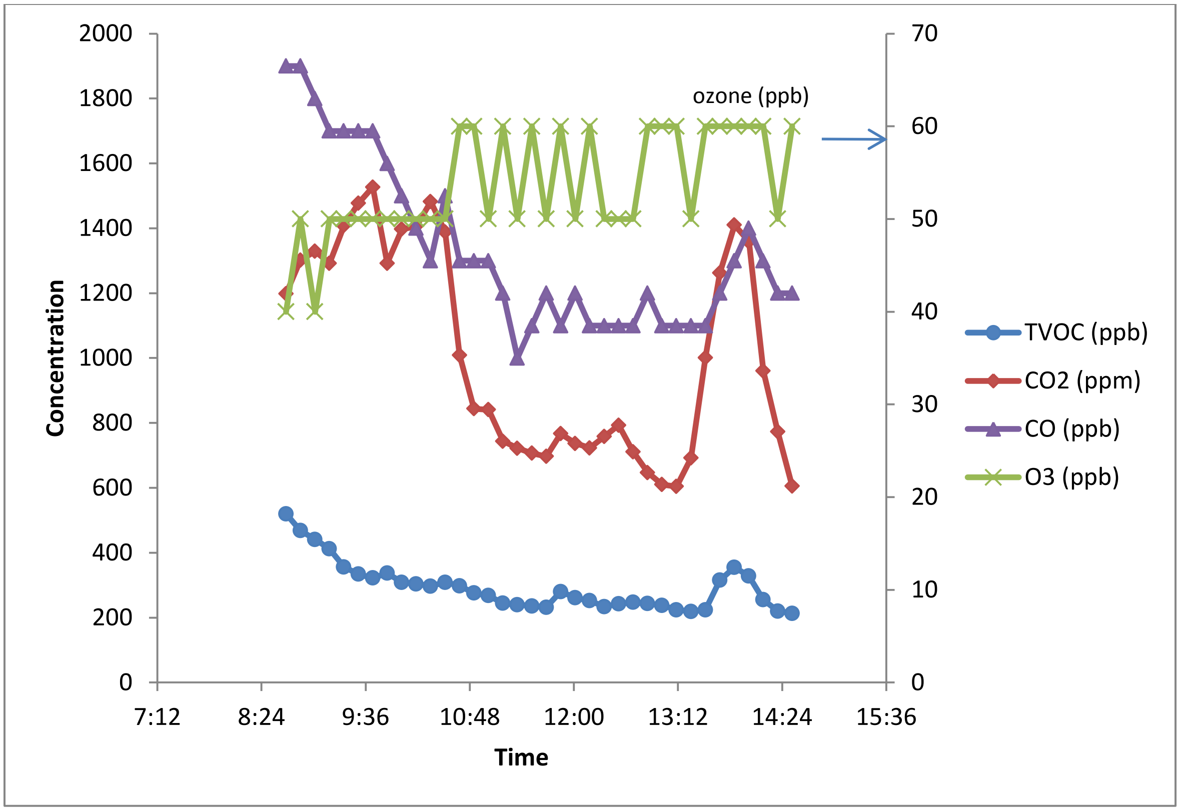


Figure 4 .27: Concentrations of TVOCS, CO_2, O_3, and CO in classroom B1.

Figure 4.28 presents the indoor concentration levels of TPM for class room B1. Some of the indoor surfaces in classroom B1 were covered with dust, so it could have affected the indoor level of TPM. Around 9:40 am when the students were active the indoor levels of particle rose. In addition, the outdoor part of the AC unit was contaminated with dirt and dust, which might have an impact on the indoor concentration of particles as the mechanical system was turned on. The maximum indoor concentration of TPM was 161 µg/ m^3 at 13:13 pm, when students cleaned the floor with floor cleaning brushes. Thus, the floor dust was suspended in the room by the students' action. The minimum concentration of TPM is 97 µg/ m^3 at 11:21 am as the classroom door had been kept closed for some time and students were not inside the room to critically impact the indoor concentration. The indoor concentration values of TPM decreased whenever the door was kept closed for some time.

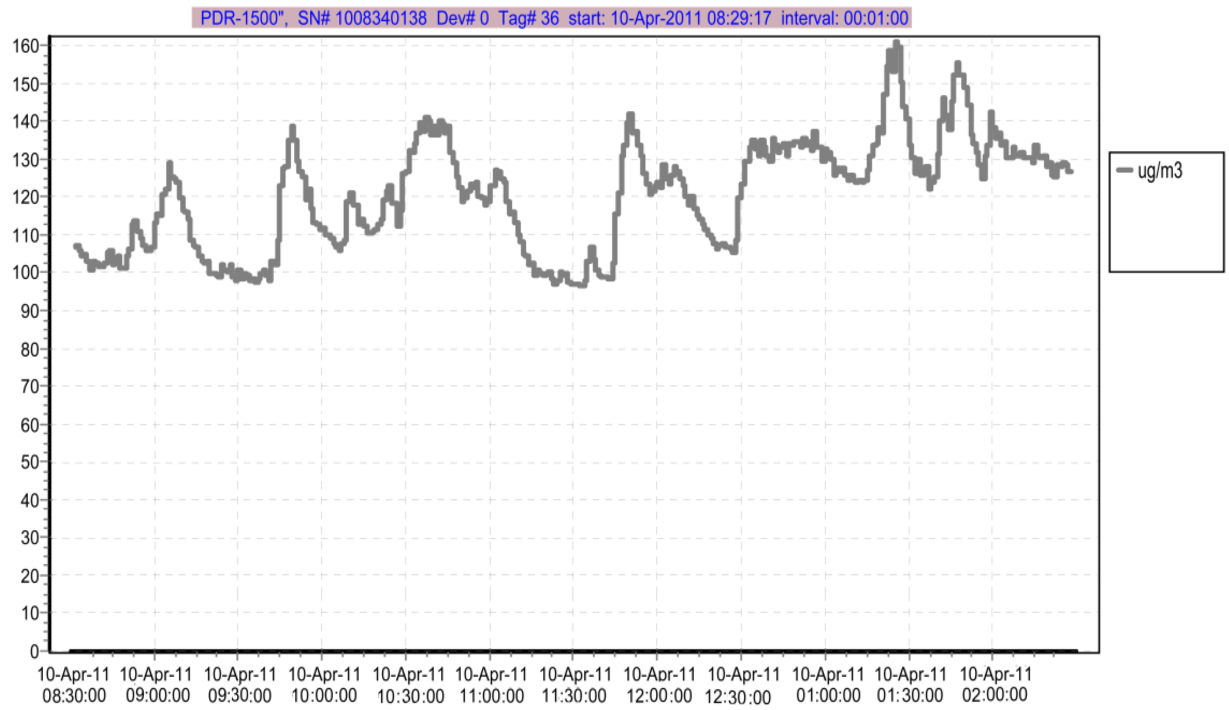


Figure 4.28: TPM Concentrations in Classroom B1

Table 4.3 demonstrates the average value of physical parameters and measured indoor air contaminates of classroom B1.

Table 4.3: Average of physical parameters and indoor contaminants

Measured component in Classroom B1	**Average**
Air Speed	4.75 m/s
Relative Humidity	40 %
Indoor Temperature	25 °C
TVOCs	293 ppb
CO_2	1013 ppm
O_3	54 ppb
CO	1333ppb
TPM	120 µg/ m3

4.2.4 Classroom B2

The investigation occurred on the 11th of April 2011. The average outdoor temperature was 27 °C. The average outdoor humidity was 63 %. The average outdoor wind speed was 18 km/h (Weather underground, 2011).

Around 8:00 a.m. the outdoor weather was very humid, because of the rain in the early-morning hours. After a while the humidity level slowly decreased. The indoor humidity level was very similar to the outdoor level. The highest value for indoor RH was 47 % at 8:35 am. Between 8:50 and 10:20 am the classroom door had been closed for the majority of the time. Only at 9:00 and 9:40 am the classroom door had been slightly opened for few a minutes. Whenever the classroom door was open the indoor humidity augmented. For example, at 12:25 pm as soon as the door was open, the indoor concentration reached 42%. The minimum value for RH was 37% at 10:15 am. The classroom door was opened for few minutes around 9:05 am and the maximum temperature which was 23°C occurred, when students were actively engaged in answering the survey questionnaires. Compared to previous classrooms studied, students of classroom B2 were more interested in participating in the survey questionnaire and were very active which could have impacted the carbon dioxide production and temperature. The minimum temperature was 21.9 °C at 12:15 pm. 13:15 pm and 14:25 pm when the classroom door was closed and mechanical systems had been working for a while without any disruption. The mechanical ventilation system which was close to the white board supplied an average air speed of 8.2 m/s at 15 cm from the diffuser and was 2 meters above the floor. The other mechanical ventilation system supplied an average air speed of 3.5 m/s at 15 cm from the diffuser and was 2 meters above the floor. The difference between the air speed supplied by each mechanical system with the same condition is considerable. Average of indoor temperature, relative humidity and indoor air speed, was 23 °C, 40%, and 5.85 m/s.

Figure 4.29 demonstrates the concentration values of indoor pollutants during the measuring time. Indoor air freshener had been sprayed few times since 8:40 am. Between 9:05 and 9:15 am an air freshener was sprayed in the room, due to this, the indoor concentration of the TVOCs quickly reached 1097 ppb. At 9:00 am the classroom door had been opened for a short time. According to the gathered information from classroom B1, it was expected that as outdoor VOCs entered the room it causes augmentation of the indoor level, but the indoor level at the time was probably much higher than the outdoor level. Thus, by opening the door, the indoor level of TVOCs probably diminished. The minimum concentration of TVOCs was 337 ppb at 14:25 pm. Students left the school by 14:00 pm consequently the room had been empty for a short period of time, air freshener had not been used for a while to affect the indoor TVOCs level, and the door had been closed. Between 8:45 to 10:15 am the door of the classroom had been closed for the majority of the time and the maximum concentration of CO_2 which was 1878 ppm occurred at 10:15 am. Thus, the mechanical ventilation systems did not properly remove the contaminants, since it does not properly dilute the concentration of carbon dioxide.

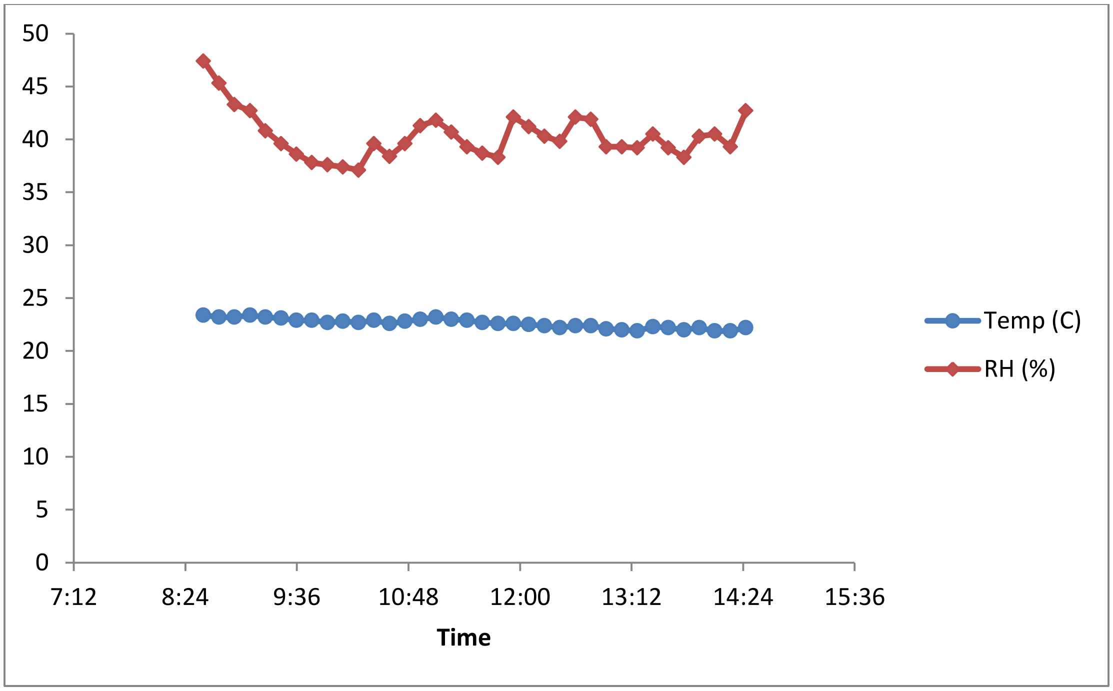


Figure 4.29: Indoor Temperature and Relative Humidity of Classroom B2

The minimum concentration of CO_2 was 689 ppm at 13:15 pm, when only 2 students were inside the classroom. The O_3 concentration is constant at 40 ppb. Usually concentration level of indoor ozone is caused by outdoor ozone concentration level. Concentration values of ozone for classroom B1 and B2 demonstrated that the region of the school is not a highly ozone-polluted area. From 9:05 am the indoor concentration values of carbon monoxide had an ascending order as soon as the door was opened for a few minutes. The maximum concentration of CO was 3200 ppb at 9:45 pm, when the door of the classroom had been opened for short period of time (a few minutes). Probably, the outdoor activity that promotes the production of carbon monoxide had been taking place between 9:00 and 10:00 am. Exhaust fume from the school buses can be one of the root causes of outdoor carbon dioxide level since school buses leave the school around 9:00 am. The minimum concentration of CO was 700 ppb at 14:25, when the door of the classroom was closed. Thus, whenever the door was open, the indoor concentration of carbon monoxide increased. The average concentration of TVOCs, O_3, CO and CO_2 were 620 ppb, 40 ppb, 1813 ppb, and 1269 ppm respectively.

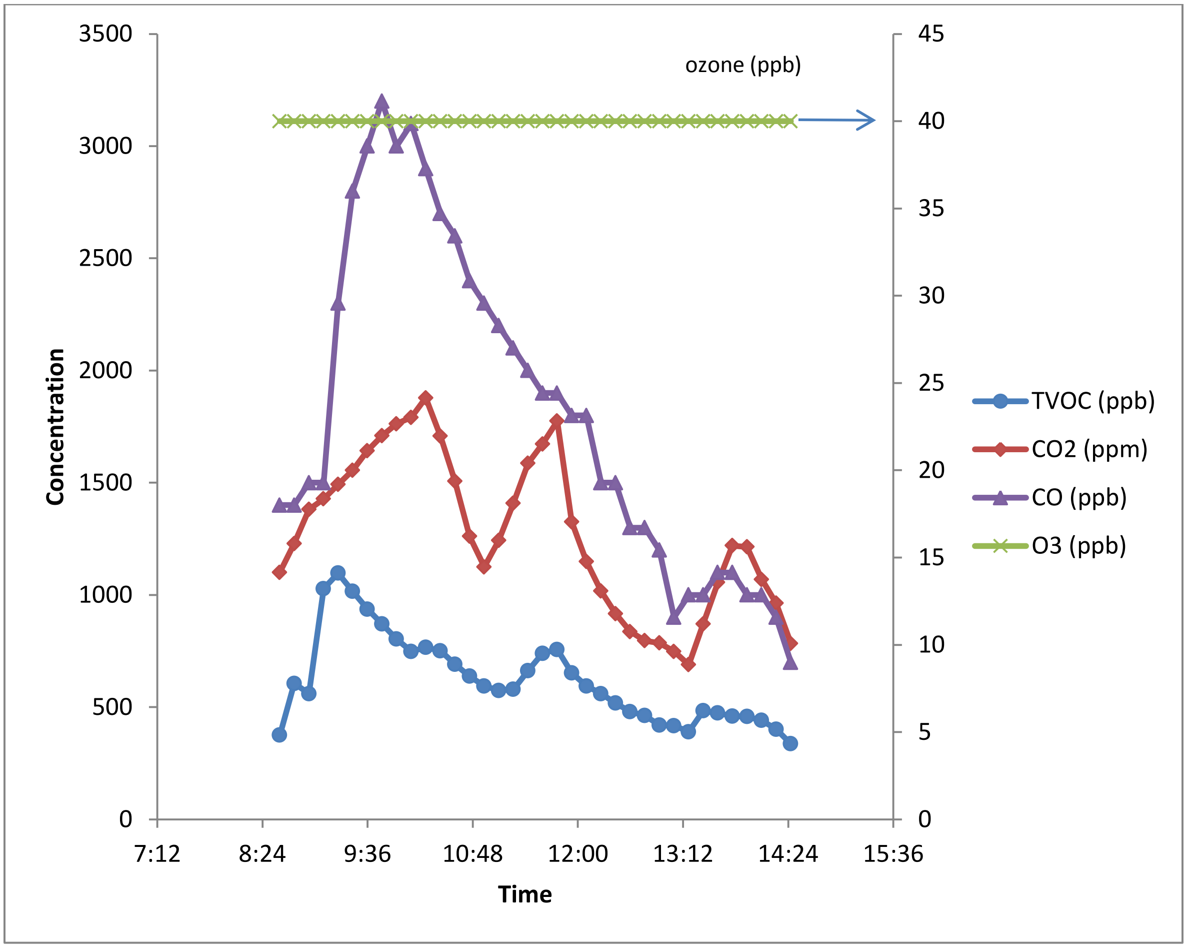


Figure 4 .30: Concentrations of TVOCS, CO_2, O_3, and CO in classroom B2.

Concentration values for total PM is demonstrated in Figure 4.31. The minimum concentration of total PM is 88 µg/ m^3 at 8:50 am. Before 8:50 am outdoor fresh air which was humid had been circulating in the room since the classroom door has been opened for almost an hour, but the level of TPM in the outdoor air was low during the morning because of the outdoor rainy air. The highest concentration value for TPM was 241 µg/ m^3 at 13:22 pm.

Between 13:17 to 13:55 pm the door had been opened. Consequently, the outdoor air which contained a high level of particles circulated in the classroom and adversely influenced the concentration level of total PM inside the room. Opening the door had influenced the peaks (peaks around 9:15, 10:30, and 11:00 am). Overall values of TPM for both of studied classrooms were high since the school building was very old. Average of indoor TPM was 102 µg/ $m^{3.}$

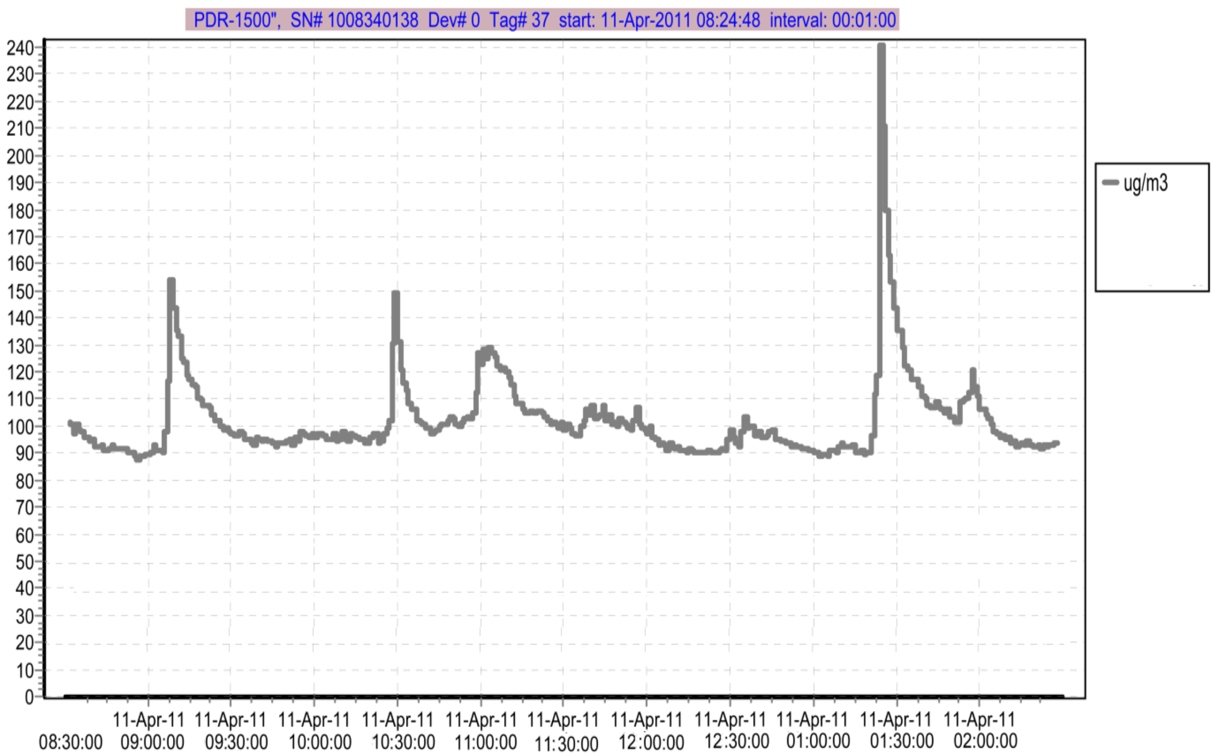


Figure 4.31: TPM Concentrations in Classroom B2

The Table 4.4 demonstrates the average value of physical parameters and the measured indoor air contaminates of classroom B2.

Table 4.4: Average of physical parameters and indoor contaminants

Measured component in Classroom B2	**Average**
Air Speed	5.25 m/s
Relative Humidity	40 %
Indoor Temperature	23 °C
TVOCs	620 ppb
CO_2	1269 ppm
O_3	40 ppb
CO	1813 ppb
TPM	102 µg/ m^3

4.2.5 Classroom C1

The investigation occurred on the 12^{th} of April 2011. The average outdoor temperature was 29 °C. The average outdoor humidity was 49%. The average outdoor wind speed was 8 km/h (Weather underground, 2011).

Figure 4.32 present values of the indoor temperature and relative humidity for classroom C1. The outdoor weather had been cloudy and rainy for some time during the investigation period. The highest value for indoor relative humidity was 49 % at 8:31 am. During the morning the outdoor weather was very humid and it affected the indoor air since the door of the classroom had been open a few times. From 1:25 to 14:11pm the door of the room had been closed for some time; hence very humid outdoor air did not particularly impact the humidity level of the indoor air. The lowest value for relative humidity was 33% at 14:11 pm. The lowest value occurred when the classroom door had been closed. The lowest value of the indoor temperature was 21 °C at 11:31 am. The majority of students felt cold because of the coldness produced by the three mechanical ventilation systems. Due to this, the mechanical system on top of the whiteboard had been turned off at 12:00 pm. Between 12:00 to 13:31 pm only two of the air conditioning systems had been used and the door of the classroom had been opened in order to warm up the room faster. Thus, the highest value of the indoor temperature which was 25°C occurred at 13:21 pm.

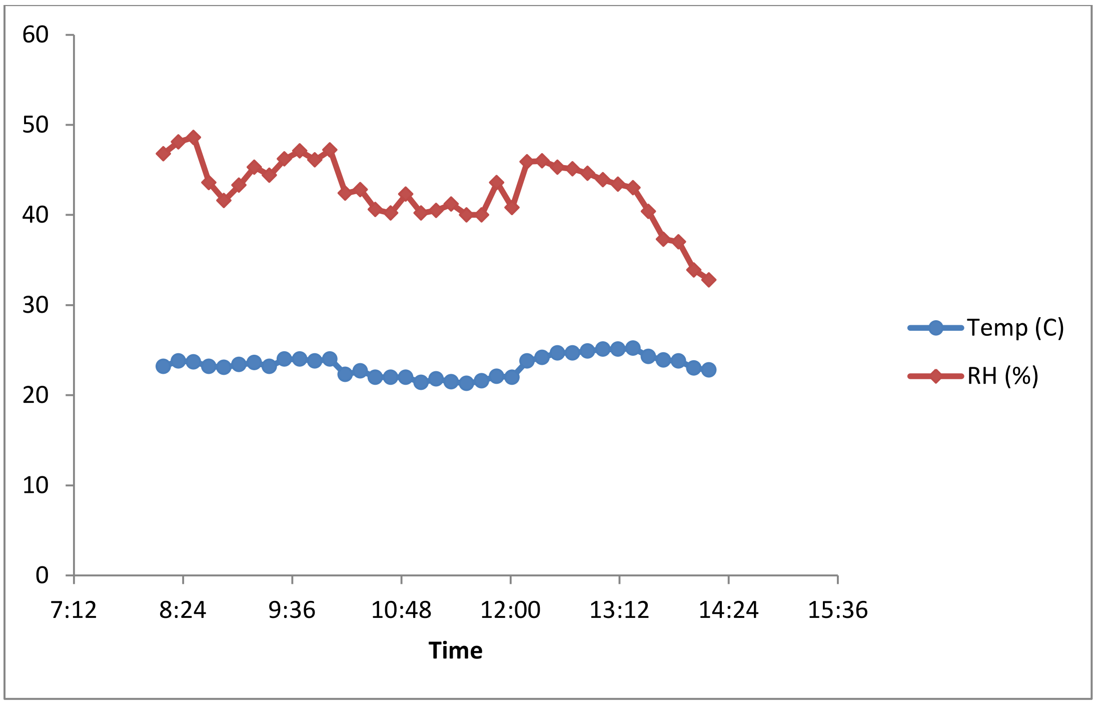


Figure 4.32: Indoor Temperature and Relative Humidity of Classroom C1

Between 13:31 pm and up to the end of monitoring the time, the three split-system air conditioners had cooled down the room. The mechanical ventilation system, which was situated on top of the whiteboard, supplied an average air speed of 5.4 m/s at 15 cm from the diffuser and was 2 meters above the floor, while other mechanical ventilation systems supplied an average air speed of 5.8 m/s, and 5 m/s. The average value of the indoor temperature, relative humidity and air speed was as follows: 23 °C, 43% and5.4 m/s.

Figure 4.33 demonstrates the concentrations of TVOC, CO_2, and O_3 for 6 hours. The maximum concentration of TVOCs was 710 ppb at 8:21 am. Values for the indoor concentration of TVOCs were very high at the beginning of the monitoring, since detergents were used for cleaning of the room shortly before the start of the school day. Between 7: 45 and 8:30 am the school buses had left the school. In addition, the classroom door had been opened many times between 8:00 to 9:40 am. Thus, the pollution produced by the buses entered the room by means of natural ventilation. Between 14:01 and 14:11 pm. the indoor concentration of TVOCs diminished since the door was not opened (it was closed for majority of time) and outdoor air did not impact the indoor air. Hence the lowest value for indoor concentration of TVOCs which was 210 ppb occurred at 14:11 pm.

Between 9:40 and 10:05 am the students had been physically active, so their bodies produce a high rate of carbon dioxide. Therefore, the maximum concentration of $CO_{2,}$ which was 1737ppm, occurred at 10:01 am. The lowest concentration of CO_2 was 598 ppm at 11:51 am. Between 10:11 and 11: 18 am there had not been any student or teacher in the classroom, so concentration values for carbon dioxide had a declining order. The minimum concentration of O_3 was 40 ppb between 8:11 and 12:51 am. The maximum concentration of O_3 was 50 ppb between 12:01 to 14:11 pm (for majority of time between 12:00 to 14:11 the indoor value of ozone was 50 ppb. After 11:40 the sun was shining and the rain stopped (clear sky). The outdoor ozone level increased as the sun shined and then entered the room whenever the door was opened. The maximum concentration of CO was 2900 ppb at 8:11 am. Very high indoor concentration values of carbon monoxide during morning had happened due to the unnecessary idling of the school buses and the high traffic rate near the school (closeness of the school to the main road and high number of vehicles around the school). Lowest concentration value of CO was 500 ppb at 11:01 am when the door was closed and no one was in the classroom. The average concentration of TVOCs, $O_{3,}$ CO and CO_2 were 380 ppb, 42 ppb, 1118 ppb and 811 ppm respectively.

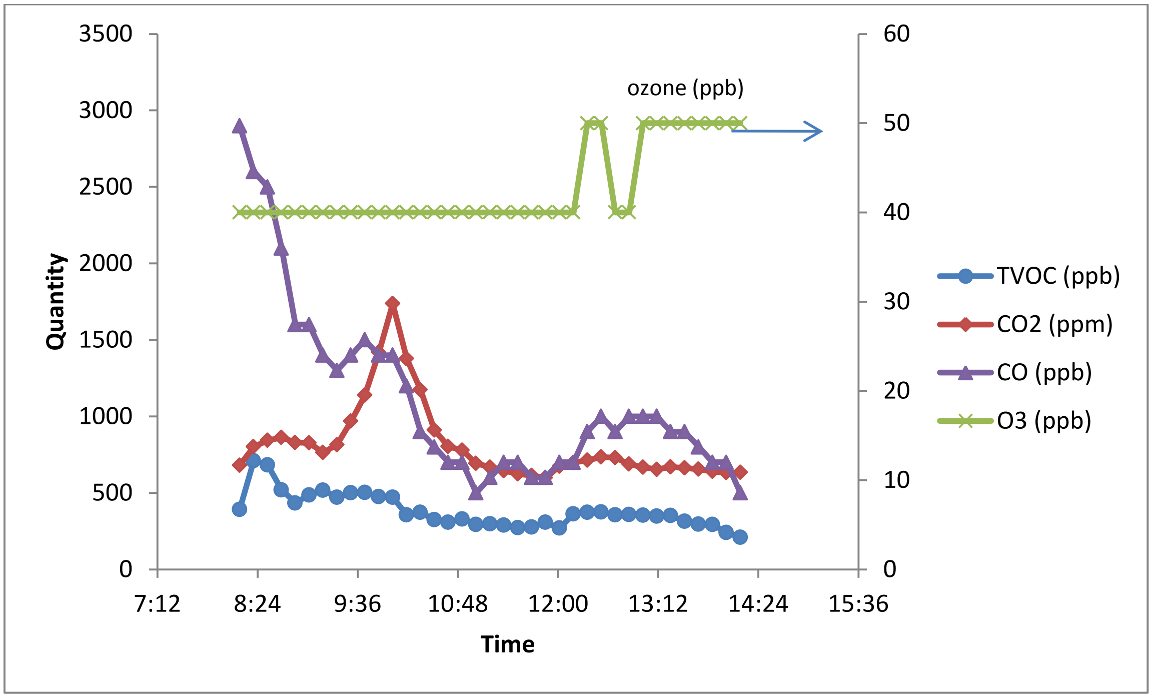


Figure 4.33: Concentrations of TVOCS, CO_2, O_3, and CO in classroom C1

Figure 4.34 shows the concentrations of TPM for 6 hours. The lowest concentration value for TPM is 116 µg/ m^3 at 14:25 pm. Between 14:16 and 14:25 p.m. the door had been closed and classroom had been empty for a while. At 9:40 am the indoor concentration of TPM was 246 µg/ $m^{3,}$ the highest indoor concentration level of TPM. The door had been opened for some time; thus the indoor concentration of TPM reaches its highest level. The average concentration value for TPM was 153 µg/ m^3.

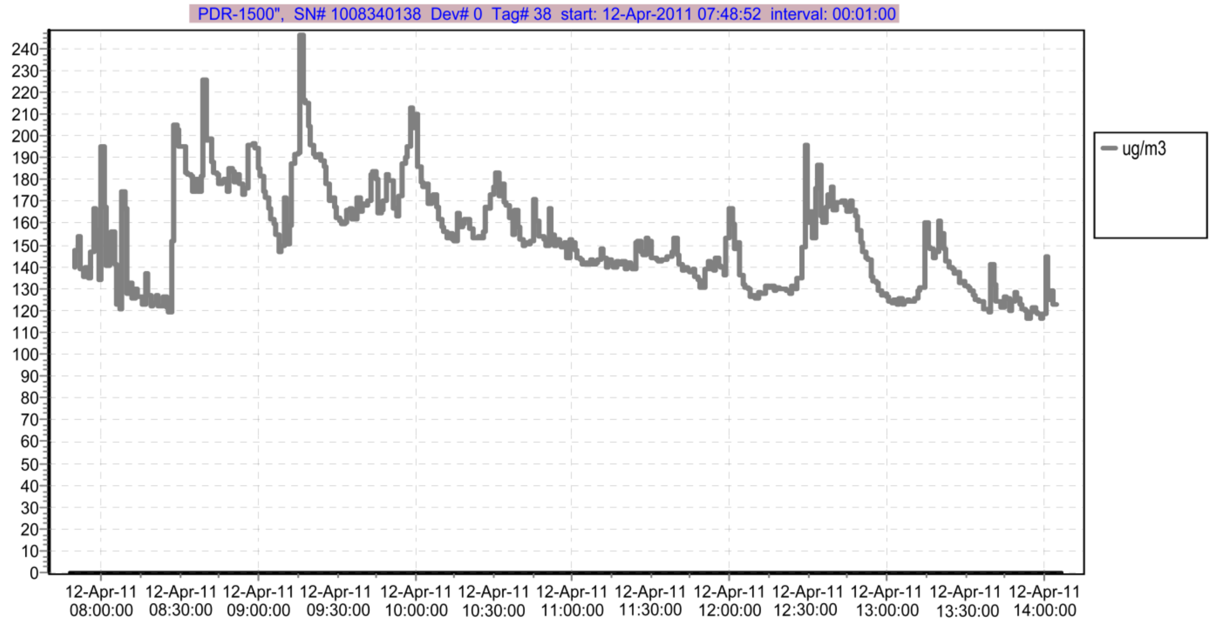


Figure 4.34: TPM Concentrations in Classroom C1

The Table 4.5 demonstrates the average value of physical parameters and measured indoor air contaminates of classroom C1.

Table 4.5: Average of physical parameters and indoor contaminants

Measured component in Classroom C1	**Average**
Air Speed	5.4 m/s
Relative Humidity	43 %
Indoor Temperature	23 °C
TVOCs	380 ppb
CO_2	811 ppm
O_3	42 ppb
CO	1118 ppb
TPM	153 µg/ m^3

4.2.6 Classroom C2

The investigation occurred on the 12th of April 2011. The average outdoor temperature was 29 °C. The average outdoor humidity was 49%. The average outdoor wind speed was 16 km/h (Weather underground, 2011).

Figure 4.35 presents concentration values of the indoor temperature and humidity for classroom C2. During the monitoring period the outdoor weather was very humid due to the rain. High humidity of the outdoor air influences the humidity of the indoor air. Between 8:15 to 11:35 p.m. one of the split air conditioner systems which were located in the back of the classroom had been turned off. While two mechanical systems were used to ventilate the room, the indoor values of relative humidity were high. At 11:35 am, when all the three mechanical systems were used, values of relative humidity decreased. The indoor relative humidity reached its highest value which was 49 % at 9:13 am. The highest value occurred when the classroom door had been opened for a short period of time. Between 13:17 and 13:45 pm all the mechanical ventilation systems had been working. Furthermore, the classroom had been empty and door had been closed. During this period of time, hot and humid outdoor air cannot easily flow into the room and no heat is produced by humans. Thus, the lowest value of indoor temperature and relative humidity occurs. The lowest value of relative humidity was 36% at 13:33 pm and the lowest value of indoor temperature was 23 °C at 13:43 p.m. Between 9:30 and 9:35 am more than 35 students were inside the classroom. In addition, the door had been opened and the hot and humid outdoor air had affected the indoor air. Thus, those circumstances caused the rise of the temperature of the indoor air. The maximum value of the indoor temperature was 27.5°C which occurred between 9:33 and 9:43 a.m. The split air conditioning system, which was positioned on top of the white board, supplied an average air speed of 4.7 m/s at 15 cm from the diffuser and was 2 meters above the floor. While other mechanical ventilation systems supply average air speed of 4 m/s. Average of indoor temperature, relative humidity, and air speed were as follows: 26 °C, 41%, and 4.2 m/s.

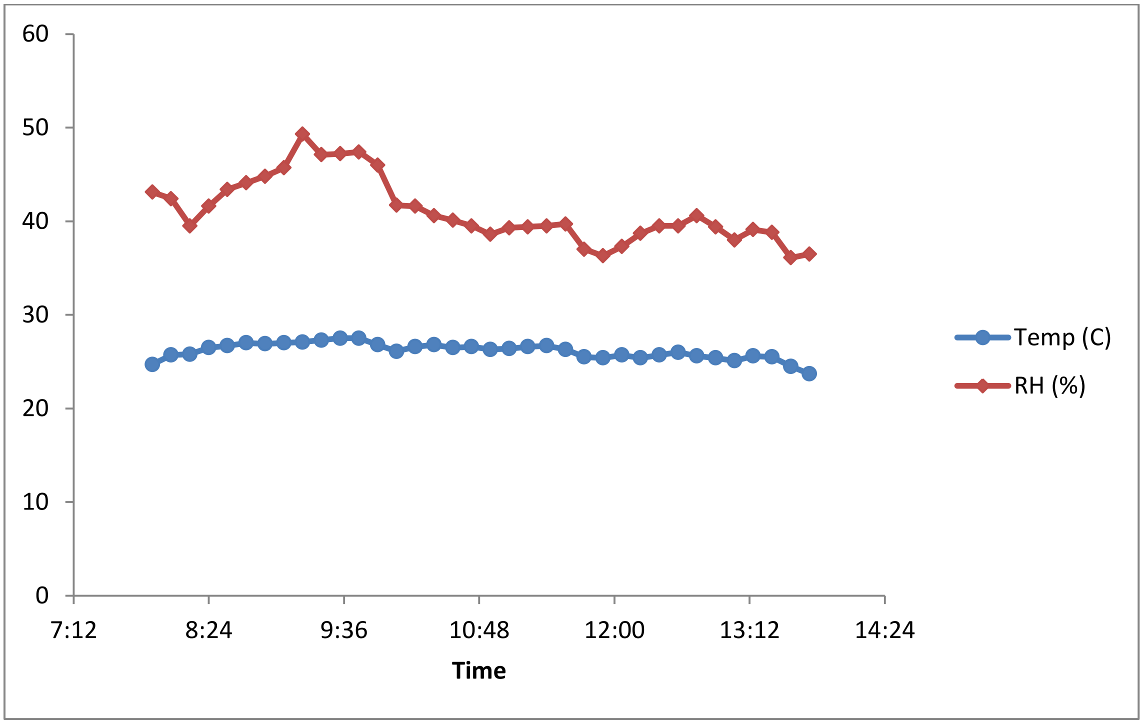


Figure 4.35: Indoor Temperature and Relative Humidity of Classroom C2

Figure 4.36 represent concentration values of TVOC, CO_2, CO, and $O_{3.}$ During the investigation the classroom door was opened several times, which impacted the indoor level of contaminants. The maximum concentration of TVOCs was 728 ppb at 8:43 am. The room had been cleaned with detergent before 7:30 am. Therefore, the indoor level of volatile organic compounds was high during the early hours of first session. Closeness of the school to public parking area could lead to possible IAQ problems. Vehicle exhaust fumes can impact the indoor concentration of various pollutants such as VOCs and CO. Air freshener had been sprayed inside the room several times between 11:30 to 11:53 am. As a result indoor concentration values of TVOCs escalated. . The minimum concentration of TVOCs was 193 ppb at 13:43 PM. Between 13:17 and 13:45 pm all mechanical ventilation systems had been working and natural ventilation had not been used. Since the door had been closed for some time, the polluted outdoor air did not affect the indoor level of TVOCs. Between 9:30 and 9:35 am carbon dioxide concentration values were listed in ascending order due to the high production rate of carbon dioxide by the occupants. The number of occupants was over 30, so the indoor amount of carbon dioxide is augmented. The maximum concentration of CO_2 was 1562 ppm at 13:13 pm while students were very active since they wanted to leave the classroom. The school timing was over at 13:15 p.m. so a few minutes before the end of class students were in a rush to collect their belongings. In addition, few students from the other classrooms were inside the room; thus, the production rate of carbon dioxide was higher than usual. Whenever the classroom's door was opened, the classroom was empty or low numbers of occupants were inside the room, the indoor values of carbon dioxide were in descending order. The minimum concentration of CO_2 was 610 ppm at 13:43 pm. The maximum concentration of O_3 was 60 ppb at various times, mostly when the door had been opened. The minimum concentration of O_3 was 50 ppb, when the door had been closed. The maximum concentration of CO was 1900 ppb at 8:53 am and from 9:23 to 9:33 am while the door of classroom had been opened for some time. The minimum concentration of CO was 800 ppb at 13:43 pm while the door has been closed (all the mechanical ventilation systems were used as the only means of ventilation). The average concentration of TVOCs, $O_{3,}$ CO and CO_2 were 524 ppb, 54 ppb, 1425 ppb and 1034 ppm respectively.

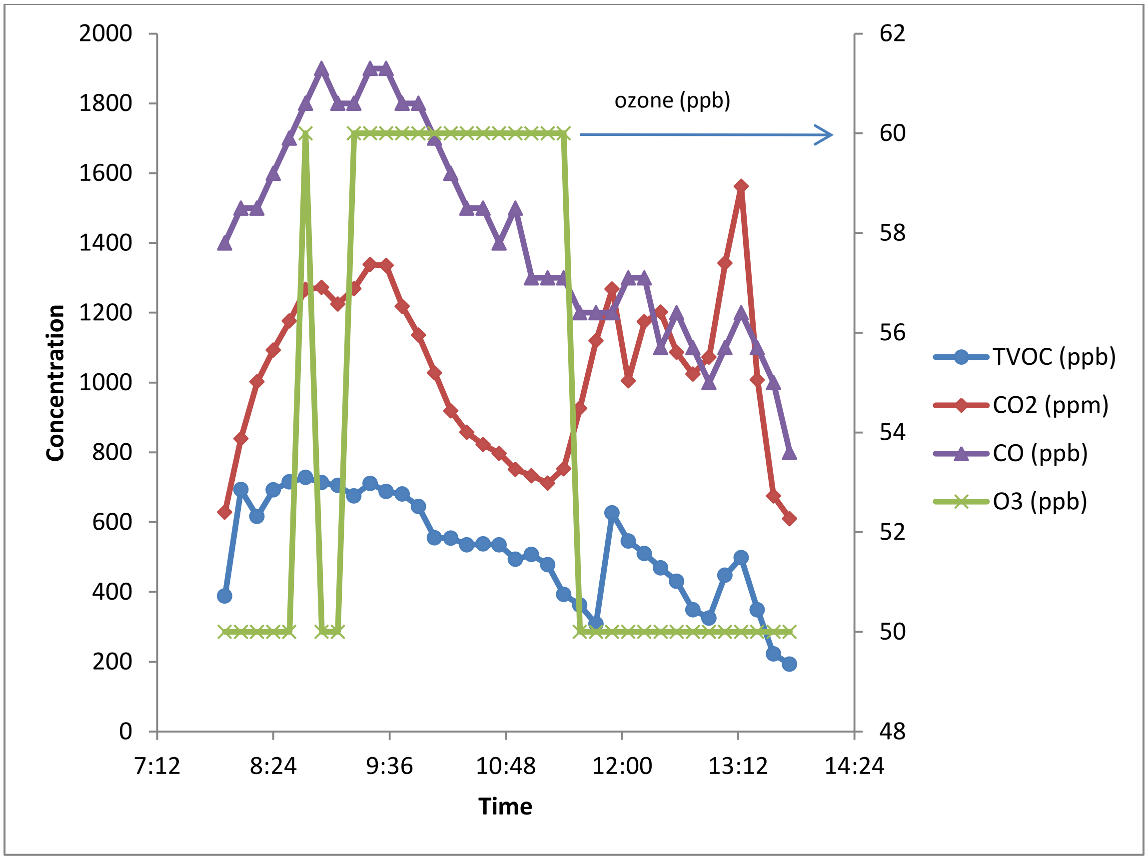


Figure 4.36: Concentrations of TVOCS, CO_2, O_3, and CO in classroom C2

Figure 4.37 reveal various concentration values of TPM for 6 hours monitoring period. The minimum concentration of TPM was 104 µg/ m^3 at 11:10 am when the classroom was empty. A concentration value of TPM began to intensify around 9:30 pm and reached its maximum value of 194 µg/ m^3 at 9:38 am. The amplification was the result of student's activity (e.g. jumping on the carpet and running around in the room) and the high outdoor level of particulate matter in the air. Polluted external air entered the room as soon as the classroom's door was opened and increased the indoor level of TPM. The average value for TPM was 136 µg/ m^3.

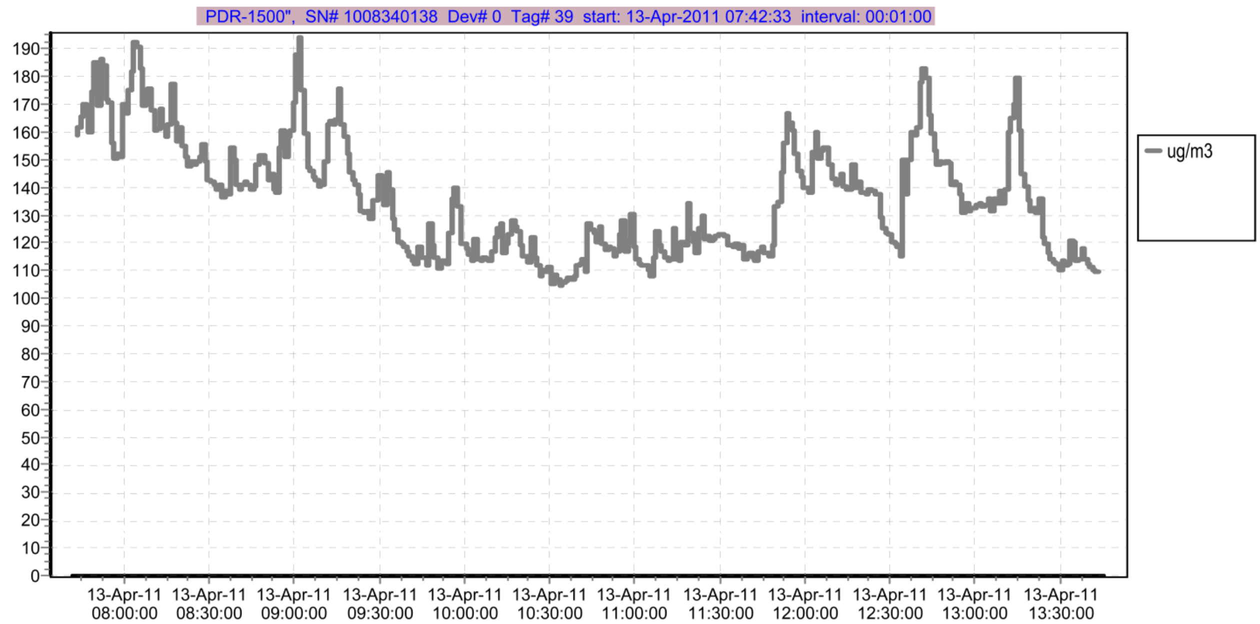


Figure 4.37: Total PM Concentrations in Classroom C2

The Table 4.6 demonstrates the average value of physical parameters and measured indoor air contaminates of classroom C2.

Table 4.6: Average of physical parameters and indoor contaminants

Measured component in Classroom C2	**Average**
Air Speed	4.2 m/s
Relative Humidity	41 %
Indoor Temperature	26 °C
TVOCs	524 ppb
CO_2	1034 ppm
O_3	54 ppb
CO	1425 ppb
TPMs	136 µg/ m^3

4.2.7 Classroom D1

The investigation occurred on the 14th of April 2011. The average outdoor temperature was 31 °C. The average outdoor humidity was 36%. The average outdoor wind speed was 14 km/h (Weather underground, 2011).

Results of 6 hours of monitoring of the indoor temperature values and the relative humidity values for classroom D1 are shown in figure 4.38. The highest indoor temperature was 22.3°C at 8:29 am. Between 8:00 and 8:35 am, the door of classroom had been opened. Thus, the indoor temperature was very similar to the outdoor temperature. At 14:04 pm the indoor temperature was at its minimum value. The door had been closed for some time since the students left the school; therefore, only the operation of mechanical systems could create a chilly indoor environment. The outdoor weather was either rainy and windy, or cloudy and windy. The outdoor environment was very humid. As a result whenever the classroom door was opened the indoor level of humidity increased. Between 14:10 and 14:34 pm the door had been opened; consequently values of indoor temperatures and relative humidity were in ascending order. At 14: 34 pm the indoor relative humidity was around 52% which is the highest value of indoor relative humidity. At 10:19 am indoor value of relative humidity reaches its minimum value which was 33.3 % since the mechanical system had been used for 60 minutes as the only means of ventilation. Both air conditioners had a supply air flow rate of 3.8 m/s. The average of indoor temperature, relative humidity and air speed were as follows: 19 °C, 37.6 %, and 3.8 m/s respectively.

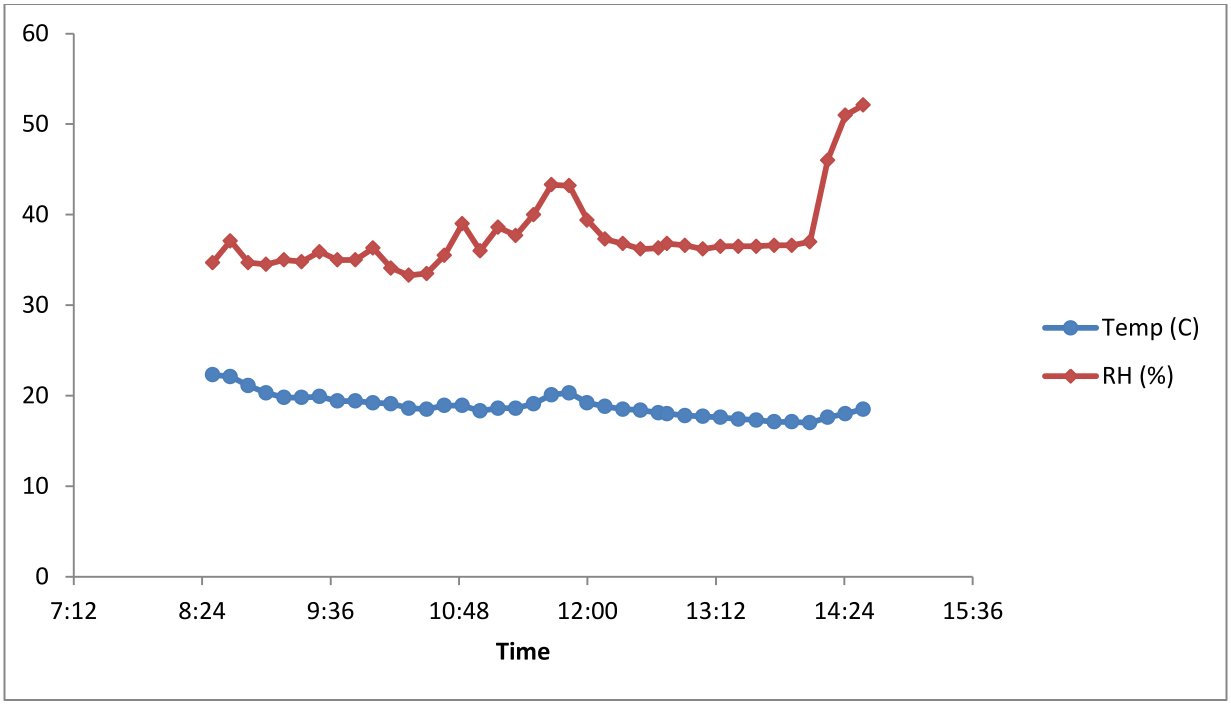


Figure 4.38: Indoor Temperature and Relative Humidity of Classroom D1

The indoor concentration values of TVOCs, O_3, CO, and CO_2 are displayed in figure 4. 39. The door of the classroom has had been opened since 8:00 am, so the outdoor air was flowing into the room. In the morning after 8:00 am the school buses started to leave the school; consequently, the indoor concentration values of TVOCs, O_3, and CO were increasing. The distance between bus loading zone and selected classrooms was less than 25 metres. In addition, loading area (parking area) of the school buses was very close to outdoor part of the mechanical ventilation system of classroom D1 and D2. Hazardous contamination produced by the buses could have highly impacted the ventilation means of the selected classroom; hence, school buses could contaminate the indoor air quality of the classrooms. Between 8:29 and 8:39 am the indoor concentration of ozone was 40 ppb which was the highest indoor value of ozone. The peak indoor concentration of carbon monoxide and TVOCs were 1500 ppb and 564 ppb at 8:39 a.m. Overall levels of pollutants were high during morning (apart from carbon dioxide). Low concentration values of TVOCs, O_3 and CO were generally occurring in the afternoon whilst the classroom was not occupied and the door was closed. Students of school D left the school early on Thursday. They generally left the classroom around 12: 05 p.m. Thus, the indoor value of carbon monoxide, ozone and TVOCs were low during the afternoon since the classroom door had been kept closed for the majority of the time apart between 14:10 and 14:34 p.m. The lowest concentration value of TVOCs was 63 ppb which occurred at 13:54 pm. The least concentration value of carbon monoxide was 100 ppb at 13:24, between 13:44 and 13:54 and 14:14 pm.

In general, the indoor concentration values of ozone were low, since the indoor concentration of ozone in the selected classroom was dependent upon to outdoor concentrations. Usually the ozone in the atmosphere level is produced, when nitrogen oxide and VOCs are combined in the presence of sunlight. The outdoor value for ozone was low. This is probably due to the weather being cloudy for the majority of time; the minimum indoor concentration of zone was 10 ppb from 12:54 to 13:04 pm. As students left the classroom by 12:05 indoor concentration of carbon dioxide were in descending order. When the door was opened at 14:10 pm the rate of carbon dioxide reduction in the room had suddenly increased.

At 14:34 pm indoor level of carbon dioxide reached its minimum level which was 569 ppm. The maximum concentration value of carbon dioxide was 2931 ppm at 9:29 am while only the mechanical system had been used as a method of ventilation and the door was closed. Outdoor air did not enter (closed door) the room to ventilate and remove the excess amount of CO_2. Generally students of selected classroom were very energetic compared to all other studied schools. Whenever they are inside the room, they had been very active. They had been moving and playing for majority of monitoring period. Thus, their activities had impacted the indoor concentration of carbon dioxide and total particulate matter. Prescribed students' activities can cause more rapid re-suspension of floor dust in the classroom. The average concentration of TVOCs, O_3, CO and CO_2 are 268 ppb, 22 ppb, 673 ppb and 1492 ppm respectively.

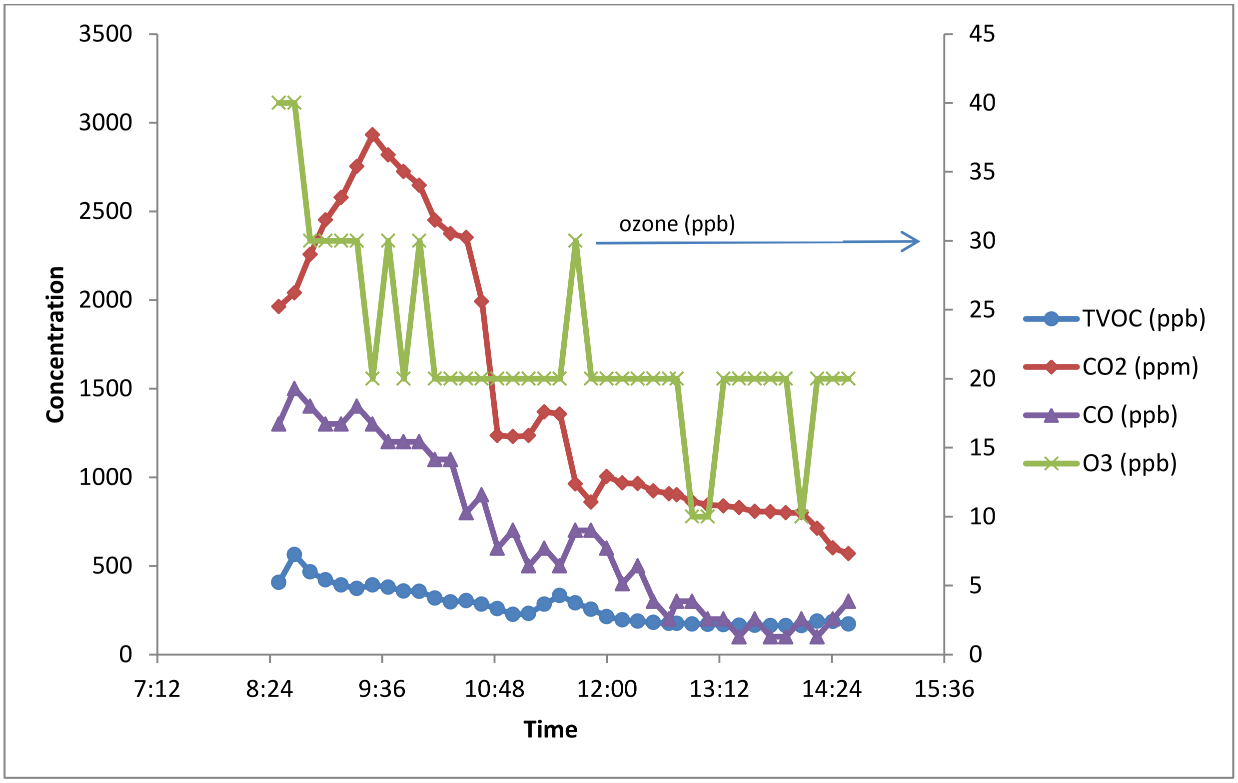


Figure 4.39: Concentrations of TVOCS, CO_2, O_3, and CO in classroom D1

The indoor concentration value of total PM in classroom D1 was presented in Figure 4.40. The door of classroom D1 had been closed for the majority of measuring time and the classroom had been empty from 12:00 p.m. Consequently the indoor level of some air pollutants would be lower in classroom D1 compared to other the studied classroom (D2). Student's activity (running) during the rush hour (closing time) affects the indoor level of TPM. It caused dust and particle on the floor to re-suspend inside the space. Thus, shortly after 11:30 pm indoor level of TPM increased. The lowest measured indoor value for TPM was 104 µg/ m3 at 14:00 pm, while the polluted outdoor air was not brought inside the room by means of natural ventilation. In addition, there was no student inside the room. The highest value for total PM was 254 µg/ m3 at 14: 11 pm. Between 14:05 to 14:20 pm the classroom had been cleaned with the help of floor brush. As the floor was cleaned particles suspend within the room environment. Unfortunately the cleaning process of classroom D1 was not very efficient. Even after cleaning the room, dust could be observed on floor and some flat surfaces in the room. In addition classroom door had been opened since 14:10 pm and polluted outdoor air came in. Lastly the school building was very old. Thus, the high indoor value for particulate matter was expected. Average concentration value of total particulate matter was 130 µg/ m3.

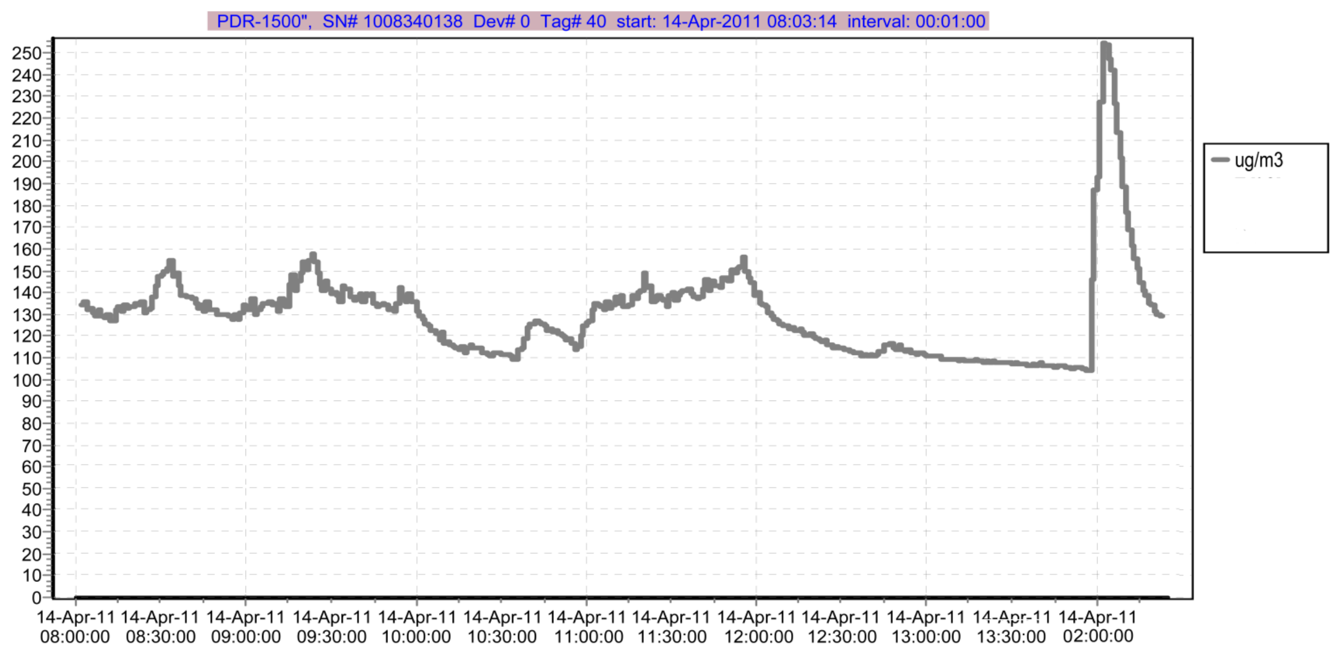


Figure 4.40: TPM Concentrations in Classroom D1

The Table 4.7 demonstrates the average value of physical parameters and measured indoor air contaminates of classroom D1.

Table 4.7: Average of physical parameters and indoor contaminants

Measured component in Classroom D1	**Average**
Air Speed	3.8 m/s
Relative Humidity	37.6 %
Indoor Temperature	19 °C
TVOCs	268 ppb
CO_2	1492 ppm
O_3	22 ppb
CO	673 ppb
TPMs	130 µg/ m^3

4.2.8 Classroom D2

The investigation occurred on the 18th of April 2011. The average outdoor temperature was 24°C. The average outdoor humidity was 65%. The average outdoor wind speed was 11 km/h (Weather underground, 2011).

The overall outdoor weather on the investigation date was very moderate. The outdoor temperature was hotter in the afternoon compared to the morning. Students started to leave the classroom at 13:05 pm and the door had been opened between 12:55 and 13:12 pm. While students were leaving the room, the temperature of outdoor air impacted the indoor temperature value. Therefore, as the door was opened in the afternoon, the indoor temperature rose. The indoor temperature and relative humidity value reached their maximum value at 13:12 pm. The highest value of temperature and relative humidity were 21°C and 56 % respectively.

The lowest value of indoor temperature was 16°C at 14:02 pm. After 13:00 pm values of the indoor temperature starts to decrease since the room had been empty for some time and the door had been closed for the majority of the time. From 13:00 pm students' body temperatures did not interfere with the coolness produced by air conditioner. Thus, the indoor temperature reached its minimum value, which was very close to the temperature supplied by mechanical ventilation device. The classroom had been empty between 9:28 and 9:58 am. In addition the door had been kept closed. At 9:52 am the indoor relative humidity was 38 % which was the minimum value of relative humidity.

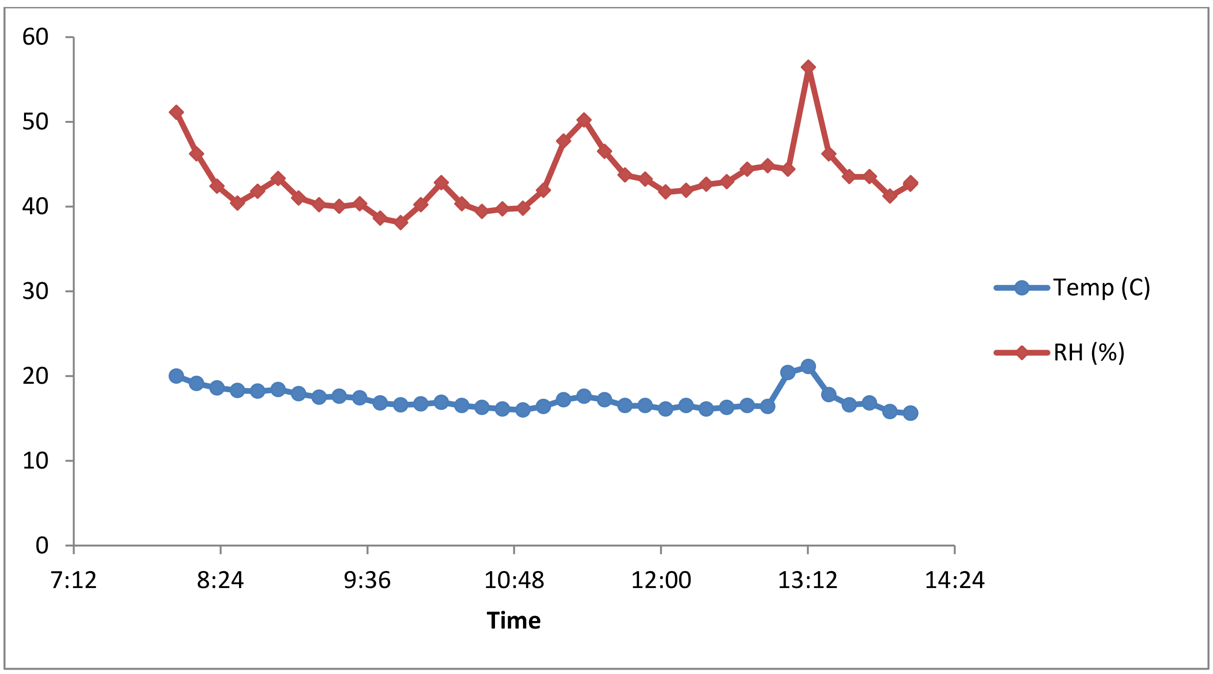


Figure 4.41: Indoor Temperature and Relative Humidity of Classroom D2

Average indoor air speed of 3.9 m/s was supplied by the mechanical ventilation system which was situated close to the teacher's desk (whiteboard) and the average indoor air speed of 3.7 m/s was supplied by the other mechanical ventilation system. The average of indoor temperature and relative humidity, and air speed were as follows: 17 °C, 43%, and 3.8 m/s.

Figure 4.42 demonstrates indoor concentration values of TVOCs, CO, CO_2, and O_3 for 6 hours. The distance between classroom D2 and the school bus area was smaller compared to distance between the classrooms D1 and the school buses loading and unloading area. As a result, pollution produced by the buses may have affected the indoor air of classroom D2 more than the indoor air of classroom D1. Similarly to classroom D1, the indoor values of volatile organic compounds, ozone, and carbon monoxide in classroom D1 were at their peak during the morning. At 8:12 am whilst the school buses were leaving the school, the indoor concentration value of TVOCs was 632 ppb which was the highest indoor level of TVOCs. At 8:02 am the indoor concentration value of carbon monoxide was 1500 ppb which was the highest indoor value of carbon monoxide. The lowest value of TVOCs and carbon monoxide occurs at 14:02 pm. As it was mentioned before the room had been empty and the door had been kept closed for some time. As a result, indoor values of contaminants decrease, since those pollutants were brought in from outdoor. The lowest indoor values for TVOCs and CO were 150 ppb and 400 ppb respectively. The peak concentration value for TVOCs occurred as the door was opened. The indoor ozone values fluctuated between 10 ppb and 20 ppb. Every time the door of the classroom was opened the indoor level reached 20ppb, but most of the time the indoor level stayed at 10 ppb. Data collected for classroom D1 and D2 demonstrated that the indoor level of ozone and volatile organic compounds generally were lower compared to the other studied classroom. Perhaps low traffic rate, Public Park, low building density (green landscape of residential villas) had contributed to outdoor ozone concentration. Between 12:02 to 12:32 pm 20 occupants were inside the classroom and the door of the classroom had been kept closed. While outdoor air did not enter the room, indoor levels of carbon dioxide were in ascending order. The highest indoor level of carbon dioxide was 2256 ppb. At 12:32 pm. the indoor concentration of carbon dioxide was at its peak, when the students were actively engaged in the class lesson and some of them are running across the room. As a result carbon production rate was higher than usual. The lowest value of carbon dioxide was 967 ppb at 8:02 am. The indoor value of carbon dioxide was low during the morning, since carbon dioxide was in an early building up stage. Indoor concentration values of carbon dioxide were in descending order between 9:28 to 11:22 am since the classroom was empty. Whenever the door was opened during the mentioned period of time, the fresh air entered the room and quickly lessened the indoor concentration of CO_2. The average concentration of TVOCs, O_3, CO and CO_2 were 319 ppb, 14 ppb, 902 ppb and 1593 ppm respectively.

Results of 6 hour indoor measurement of total PM for classroom D2 are shown in the figure 4.43. The least concentration value for total PM was 124 µg/ m^3 at 10:17 am, while no one was in the room and classroom door had been closed for some time. The indoor air of classroom D2 was probably highly polluted by fine particles created by vehicle exhausts since the classroom D2 was very close to school bus loading/unloading district. Between 11:00 to 11:20 am the classroom door was opened for few times for one to two minutes. Thus, indoor concentration values of TPM were in ascending order. Between 12:45 to 13:00 pm students were active since the school was closing (end of school day) and the classroom door was open there was an increase in pattern of TPM concentration while the door was opened and students were packing, but as students left the classroom the indoor concentration of TPM decreased. Suddenly indoor concentration of TPM started to increase after few minutes. Traffic increased around 13: 05 while school buses started idling (rush hour) and vehicle idling around schools (parents' and staff vehicles). Hence, outdoor level of TPM amplified and affected indoor level of TPM. Highly polluted outdoor air came inside the classroom during the rush hour and impacted the indoor environment. Between 13:20 and 13:35 pm the room had been cleaned. Cleaning process (using floor brush) of the classroom usually cause a re-suspension of the indoor dust. Thus, the indoor values of total PM were generally high during cleaning activity. The peak indoor value of total PM was 274µg/ m^3 at 13:30 p.m. The average indoor value of total PM was 157 µg/ m^3. Average values of all measured parameters are shown in Table 4.8.

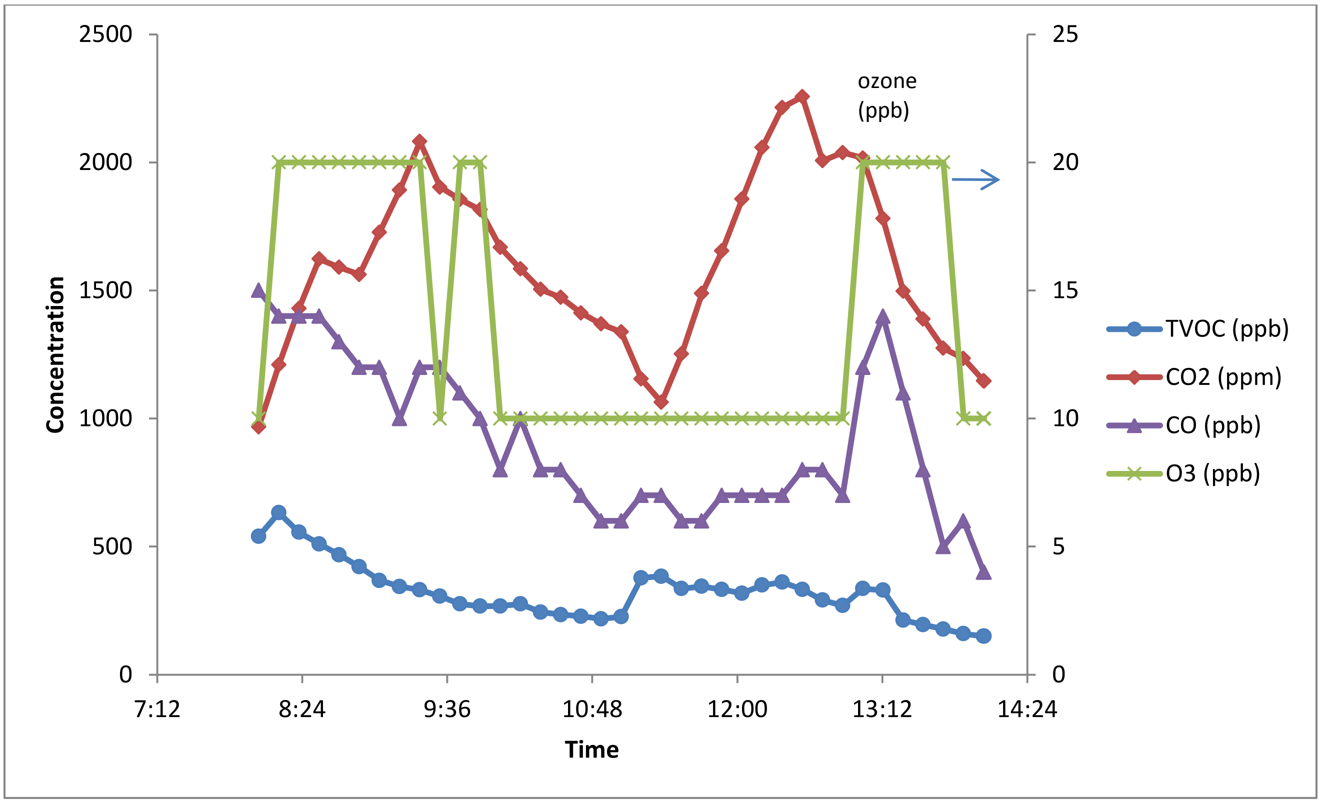


Figure 4.42: Concentrations of TVOCS, CO_2, O_3, and CO in classroom D2

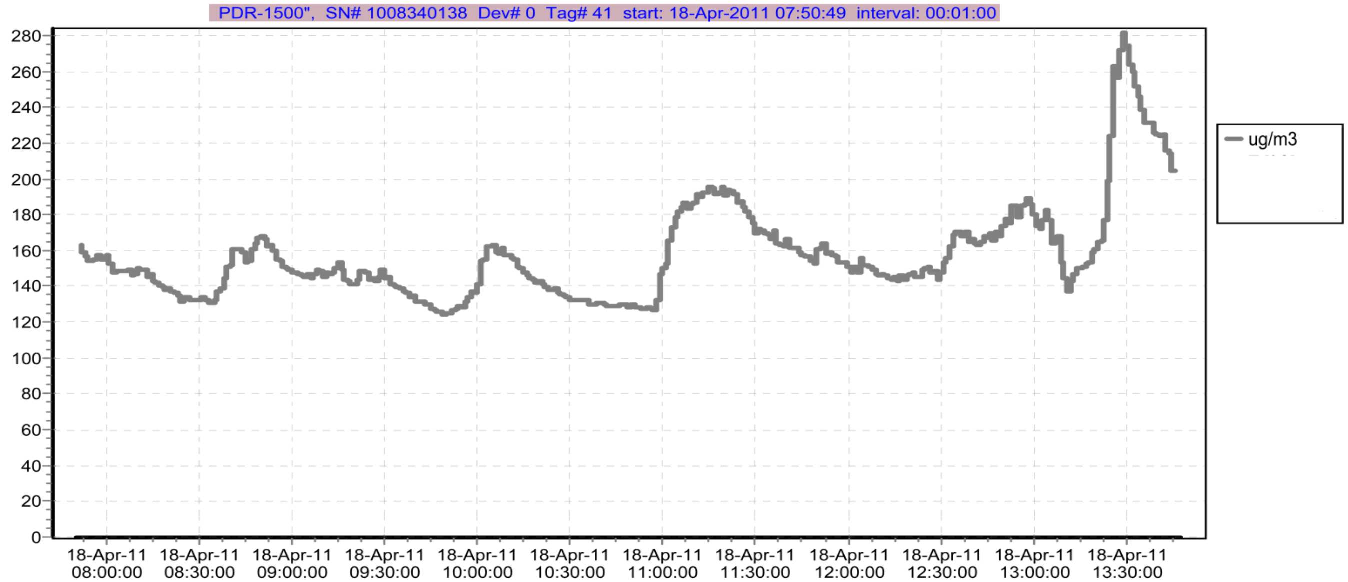


Figure 4.43: TPM Concentrations in classroom D2

Table 4.8: Average of physical parameters and indoor contaminants

Measured component in Classroom D2	**Average**
Air Speed	3.8 m/s
Relative Humidity	43 %
Indoor Temperature	17 °C
TVOCs	319 ppb
CO_2	1593 ppm
O_3	14 ppb
CO	902 ppb
TPMs	157 µg/ m^3

4.3 Subjective Study

The result of the survey questionnaire can help the school to manage and control the potential harmful effects of indoor air contaminants of the classroom and improve the health and comfort status its students. In addition, if the result of survey questionnaire showed that the majority of the occupants were not satisfied with the thermal condition of the classroom, then the decision makers may take a required action to improve the ventilation system of the classrooms, in order to enhance the comfort level of its occupants.

Some general pieces of information must be addressed before analysing the data of survey questionnaire. Firstly, generally all the schools had their own dress code for students. Thus, students wore a special uniform whilst they attended school. In order to create comfortable clothing, which is suitable for Dubai's weather and for the youngsters, uniforms in all selected schools were made from cotton. In addition, styles of their uniforms were a little loose. Some students wore additional garments under their school uniform. Therefore, their thermal sensations were varied. Secondly, estimated metabolic rates during the survey were almost similar for occupants of selected classrooms. The estimated metabolic rate was based on ASHRAE 55-2004. During the time that the students filled out the thermal comfort questionnaire, the estimated metabolic rate was around 1.2 met which was similar to the time they performed their schoolwork. Thirdly, some questions such as; the number of days that the students missed the school were cancelled due to lack of proper response. Students could not remember how many days they had been absent or they could not relate their health status to the number of days they missed school. Fourthly, the teacher's response was analyzed separately, since adults' reactions to indoor air pollutants and indoor physical parameters are usually different than youngsters. The next point was that 'point-in-time' or at the moment survey questionnaires were used, the students were not able evaluate the indoor environment for past few weeks. They might not be able to determine how they felt during previous days. Finally, results were compared with thermal sensation scale which was suggested by ASHRAE. It deploys a continuous seven-point scale (very cold, cold, slightly cool, neutral, slightly warm, warm, and hot). It is believed that thermal sensation scale represent thermal satisfaction when majority of results are in central three scales (slightly cool, neutral, and slightly warm).

4.3.1 School A

The survey was conducted in the morning between 8:35 and 9:10 am in classroom A1 and between 8:35 and 9:12 am in classroom A2. During the surveying period in selected rooms only mechanical systems are used for regulating indoor air. Nineteen students from classroom A1 and twenty students from classroom A2 had completed survey questionnaire. The range of the students' ages in school A was between 7 and 10 years old. The average age of students in classroom A1 and A2 was 8 years old.

Figure 4.44 and Figure 4.45 demonstrates thermal sensation of students' (classroom A1 and A2) based on the students' answers. The indoor air speed for both of the selected class rooms was 3.7 m/s. During the survey in classroom A1 indoor temperature was around 26 °C, and relative humidity was around 30%.

More than 78% of the students and their teacher felt that the humidity and air speed were acceptable and they felt comfortable. The outcome of Classroom A1 demonstrated that the majority of responses were on the warm side of the scale. Around 42% of students in classroom A1 felt hot in the indoor environment of the classroom, 21% of students felt very hot and 21% of them felt slightly warm. Almost 64% of them preferred the room to be cooler and 36% of them preferred no change. However, ideal activity for some students (37%) to feel thermally comfortable was by switching on air conditioning system, but most of students in classroom A1 assumed that the mechanical systems could not successfully cool down the indoor environment. Few students (three) assumed the sun heat was the major cause for the hot indoor temperature since they sat near the window. Therefore, their ideal activity to achieve comfort was to change the location of their seat. The overall insulation value of clothing in classroom A1 was high since the majority of the students wore more than three layers of clothing. Around 60% of students wore 3 layers of clothing in the top half of their body. However, only 5% of students believed by removing the layer of garments, they could feel thermally comfortable. The teacher of classroom A1 feels slightly cold. She sat closer to mechanical ventilation system and she wore 2 layers of clothing in upper and lower half (without considering shoe and socks) of her body. Her sitting area in the classroom and her clothing impacted her thermal sensation, but also adult's thermal sensation was different than children. The teacher had a lower activity level compared to the students. Probably high layers of clothing (excess garments) and an improper performance of ventilation system were root causes for warm, slightly warm and very hot response from students of Classroom A1.

Results of the survey questionnaire in classroom A2 was very different compared to classroom A1. Throughout the survey in classroom A2, the average indoor temperature and relative humidity were 22°C and 30%. The majority of the students' responses were in three central categories. Around 40% of the students felt neutral, 35% felt slightly cool and 15% of them felt slightly warm. More than 73% of students had 2 layers of clothing in the upper half of their body. Classroom A2 had lower indoor air temperature and the majority of students had fewer layers of clothing (lower insulation value) compared to classroom A1; thus, the mentioned parameters created a more comfortable situation for many of the occupants. The majority of students and their teacher felt the indoor air speed and humidity were acceptable. Around 65% of students and their teacher believed that the indoor temperature was fine and they didn't want any change. Only 10% of them felt cold which can be a result of low insulation value of their clothing.

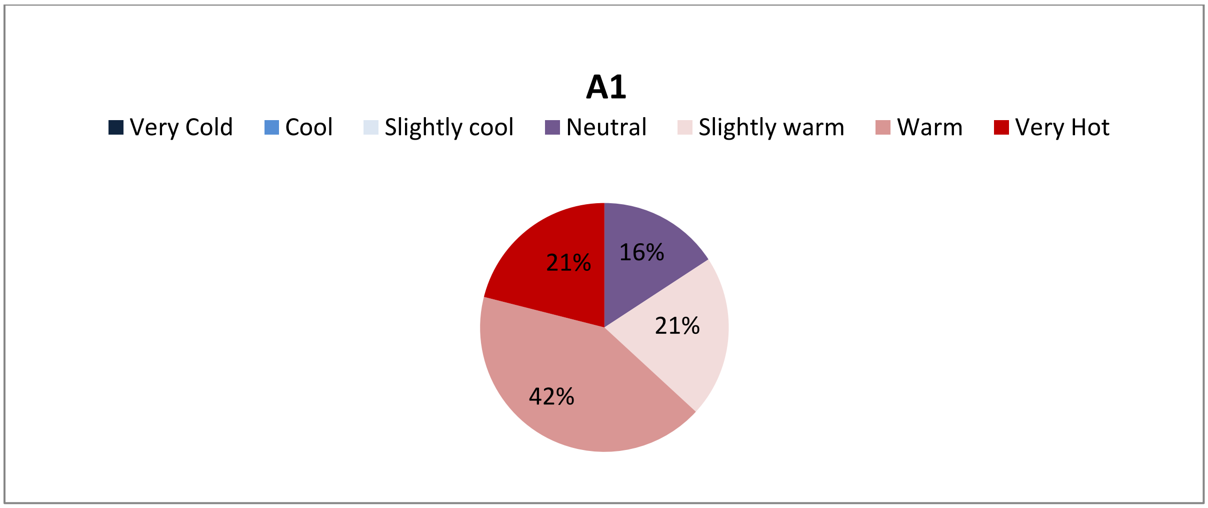


Figure 4.44: Distribution of Students' Thermal Sensation Votes in Classroom A1

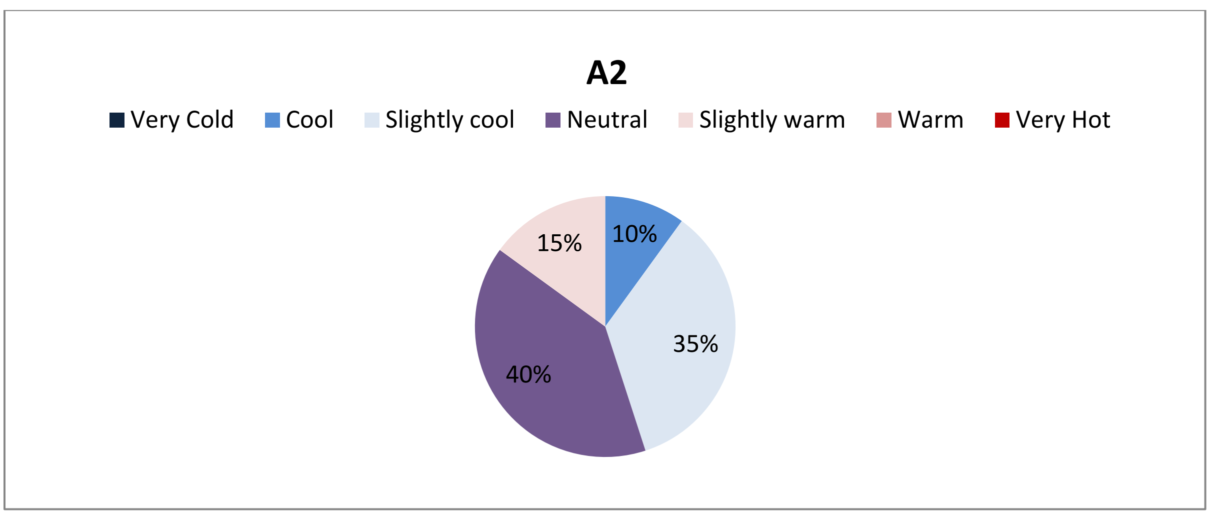


Figure 4.45: Distribution of Students' Thermal Sensation Votes in Classroom A2

Figure 4.46 and 4.47 revealed satisfaction levels of students with their thermal environment. The majority of occupants in classroom A1 preferred a cooler indoor environment, but they felt neutral about the indoor environment of their classroom. Outcome of survey in classroom A1 implied that the overall neutral vote were not always an indicator of the occupants' preferred thermal condition. In both classrooms the door had been closed for the majority of the surveying period; thus, mechanical system of classroom A1 did not successfully create suitable a room temperature that could create a satisfactory indoor environment. The majority of the students in classroom A2 were pleased with the physical parameter of the indoor environment, since they vote; very satisfied (29%), satisfied (24%), and fairly acceptable (24%). Generally students of classroom A2 had responded neutral or satisfied with their environment, so they felt comfortable with the thermal conditions of the room.

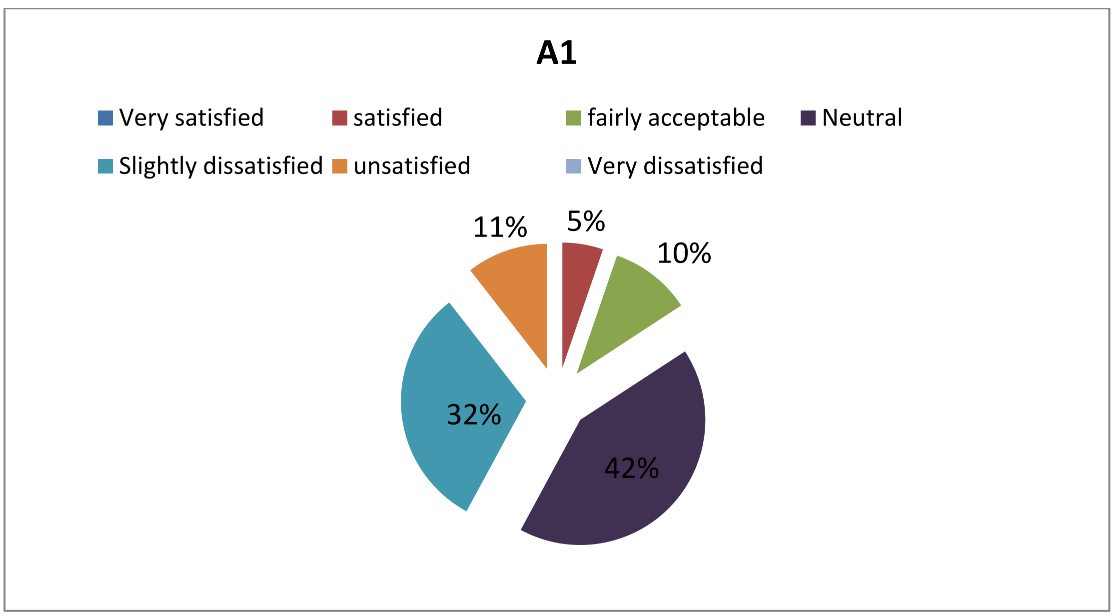


Figure 4.46: Students satisfaction response to indoor physical parameters (temperature, humidity, air speed) in classroom A1

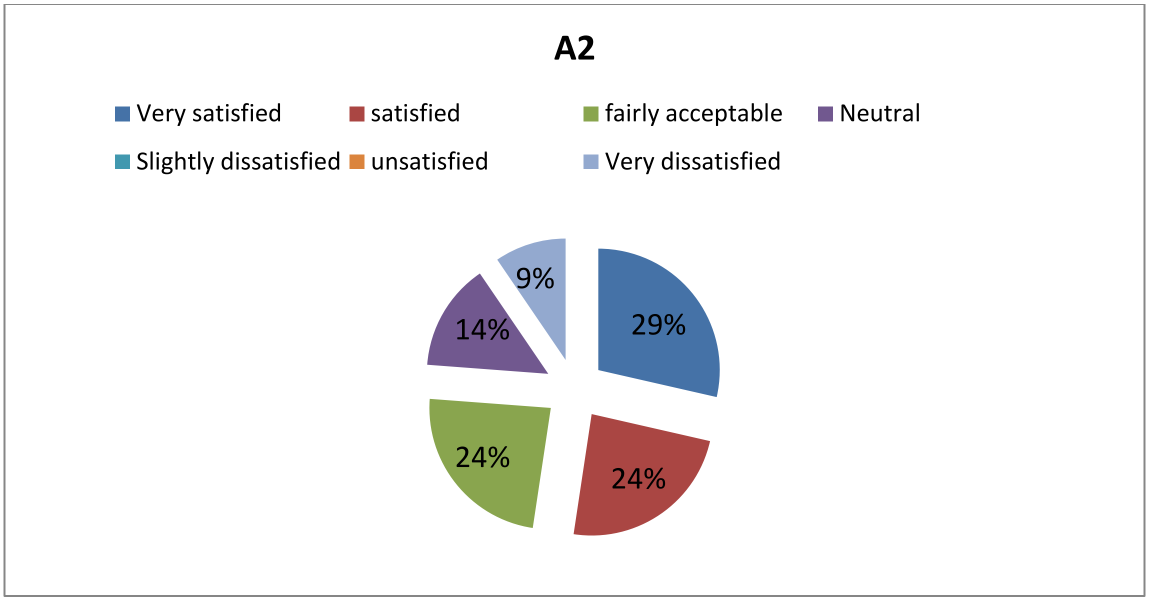


Figure 4.47: Students satisfaction response to indoor physical parameters (temperature, humidity, air speed) in classroom A2

Figure 4.48 and 4.49 demonstrated the health status of students in classroom A1 and A2. In general, school A outcomes demonstrated a low complaint rate. Not many students claimed that they experienced physiological symptoms.

Results of classroom A1 demonstrated that only 5% (one person) of all the students had health condition problems such as allergy to dust, allergy to mould and asthma. Almost 15 % of them had an eczema problem. Student's allergies and asthma problems may have been caused by the exposure to the classroom air pollutants or might have some other roots, but high levels of contaminants without doubt would accelerate the asthma attack or allergy reaction. Students who had health problems condition were more sensitive to indoor air contaminants compared to others. Around 21% (one to three days in the previous 4 weeks) of students in classroom A1 had experienced dry or itchy skin which was the most common symptom. Other prevalent symptoms were tired or strained eye

(16%), difficulty in remembering things or difficulty in concentrating (11%), sore or dry throat (11%), pain or discomfort (10%), itchy eye (16%), headache (11%), nervousness (11%) and sneezing (16%). The remaining symptoms did not have significant a number of complaints. All respondents declared that symptoms occurred one to three days per week during last 4 weeks. Majority of the interviewed occupants declared that whilst they were away from the school they felt better. Symptoms started to get better shortly after students left school; thus, the described circumstances resembling Sick Building Syndrome (SBS). The teacher from another third grade classroom responded to the survey questionnaire since classroom A1 teacher was not present. She did not have any health problems. She had been spending majority of her working hours in another classroom, so her responses would not be really useful for circumstances in classroom A1.

The total numbers of students who had health condition problems were very few in classrooms A2. Classroom A2 responses revealed that 5% (one person) suffered from asthma, 10% were allergy to dust and 15% suffered from eczema. Students of classroom A2 complained about the following symptoms: dry or itchy skin (15%), sneezing (15%), unusual fatigue (10%), headaches (10%), dry or irritated eye (10%). Most of students stated that they suffered from those symptoms 1 to 3 days during the previous weeks. Interviewed students stated that the most common symptoms (e.g. sneezing and irritated skin) disappeared whilst they were away from school. The teacher of classroom A2 stated that during most days (at least 3 times a day), she suffered from a headache, fatigue and dizziness whilst she is in school. She felt better once she left the school. She often (several times a week) used the schools' photocopier, laser printer. She was probably exposed to high levels of ozone during school hours. In addition, she used material that released VOCs such as glue, spray etc. The overall health condition of the occupants in classroom A2 was better compared to classroom A1. The level of total particulate matter was enough to causes undesirable symptoms in sensitive occupants in selected classrooms of school A.

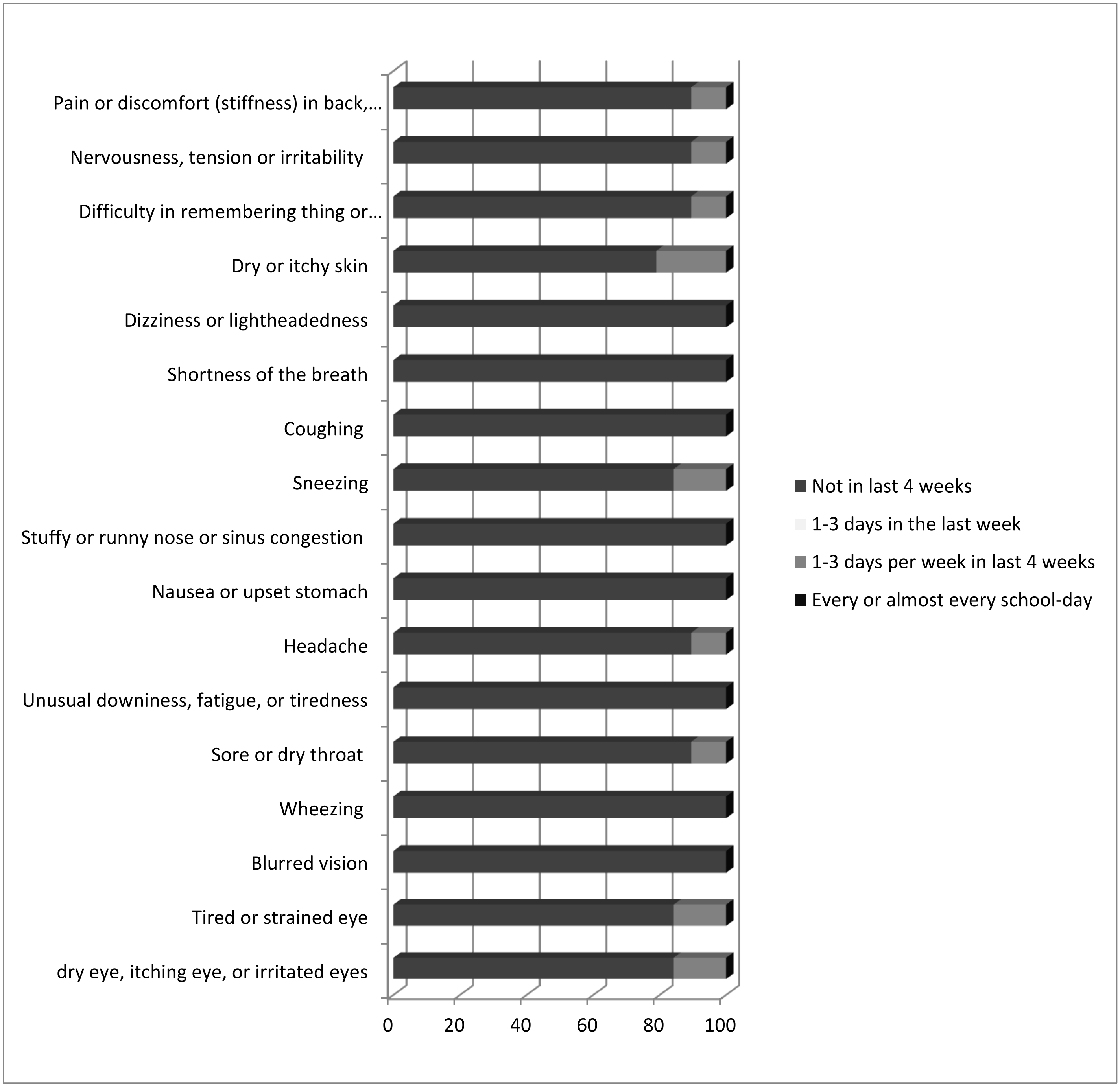


Figure 4.48: Physiological Symptoms in Classroom A1

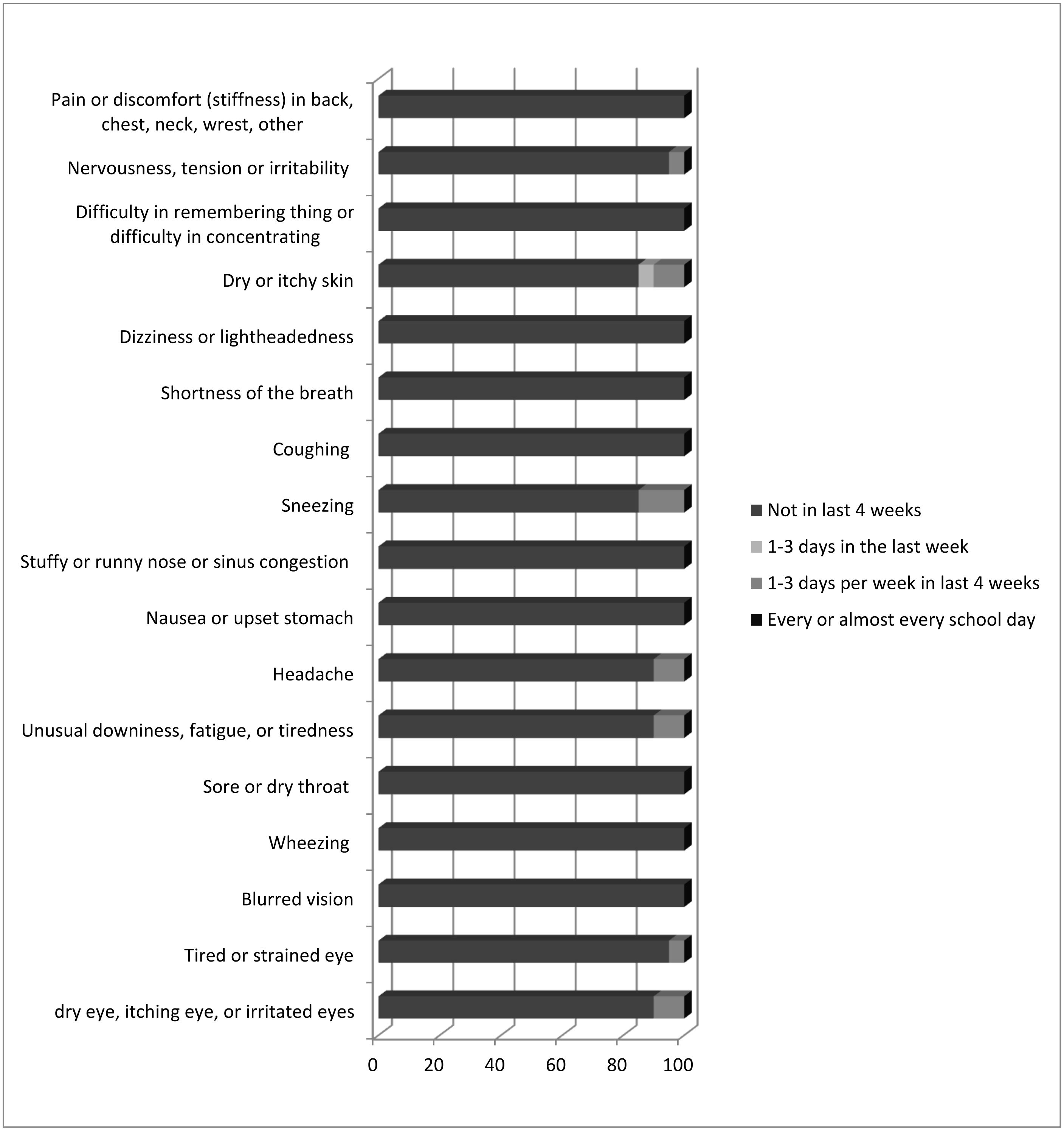


Figure 4.49: Physiological Symptoms in Classroom A2

4.3.2 School B

The survey was carried out in the morning between 8:45 and 9:45 am in classroom B1 and 8:50 to 9:45 am in classroom B2. Throughout the surveying time in both selected rooms only mechanical systems were used for regulating the indoor air and the classrooms' door had been closed for majority of the surveying time. Twenty students from classroom B1 and eighteen students from classroom B2 had completed survey questionnaires. The age of the students in school B was between 7 and 9 years old. The average age of students in the selected classrooms was 8 year-old. Figure 4.50 and 4.51 display students' thermal sensation votes (classroom B1 and B2).

Throughout the survey in classroom B1 average of indoor temperature was around 24.5 °C, relative humidity was around 39% and indoor air speed was 4.75 m/s. Students' feelings were strong on the warm part since most common responses are warm (40 %), slightly warm (20%) and very hot (20%). The majority of the students (85%) and their teacher felt that the indoor humidity level was acceptable. Wind speed was accepted by 65% of occupants. Around 60% of occupants (an overwhelming majority) preferred a cooler indoor temperature and they all asked for more air movement. Thus, many of the occupants experiencing not enough air movement while they were in the room. Close to 30% of occupants did not desire any change to their indoor environments.

Technique (activity) adopted by the students to reach thermally comfortable condition when they feel too cold or cold are as follows: switching the air conditioning system on or off (40%), switching the fan on or off (40%), opening the windows (15%) and adding or removing layers of clothing (5%). The results demonstrated that many of students in classroom B1 felt the air conditioning system could not create a thermally comfortable environment, so they chose other ventilation means such as a fan or an open window in order to produce an acceptable thermal setting. The school has its own uniform dress code and students were not able to add or remove layers of garments that they wore under their uniform. Thus, they could not change personal variables in order to enhance their comfort condition. More than 70% of students wore 2 layers (jumper and blouse) on the upper half of their body. Without considering shoes and socks, some students wore excessive layers in lower half of their body such as 4 layers (10%), 3 layers (45%). The remaining (45%) wore 2 layers of clothing.

The average of indoor physical parameters in classroom B2 during the survey wore as follows: the indoor temperature (23°C), RH (41%) and the indoor air speed (5.85 m/s). Most of the participants (45%) voted for slightly cool. About 22% felt cold (cool) and 33% felt neutral. All respondents (teacher and students) felt comfortable with the indoor air speed. In addition 89% of the occupants felt comfortable with humidity levels of classroom; only 11% of students felt the room was very humid. The overall occupants' thermal preference responses demonstrated that 100% of the occupants did not want any change to the classroom thermal environment. All the occupants of classroom B2 wore 2 layers of clothing in upper and lower halves of their body. Therefore, they all have had a very similar thermal insulation value. The adapted method for respondents to achieve comfortable condition when they felt too warm or too cool was is to turn the air conditioning system on or off (77%) and to add or remove layer of garments (23%).

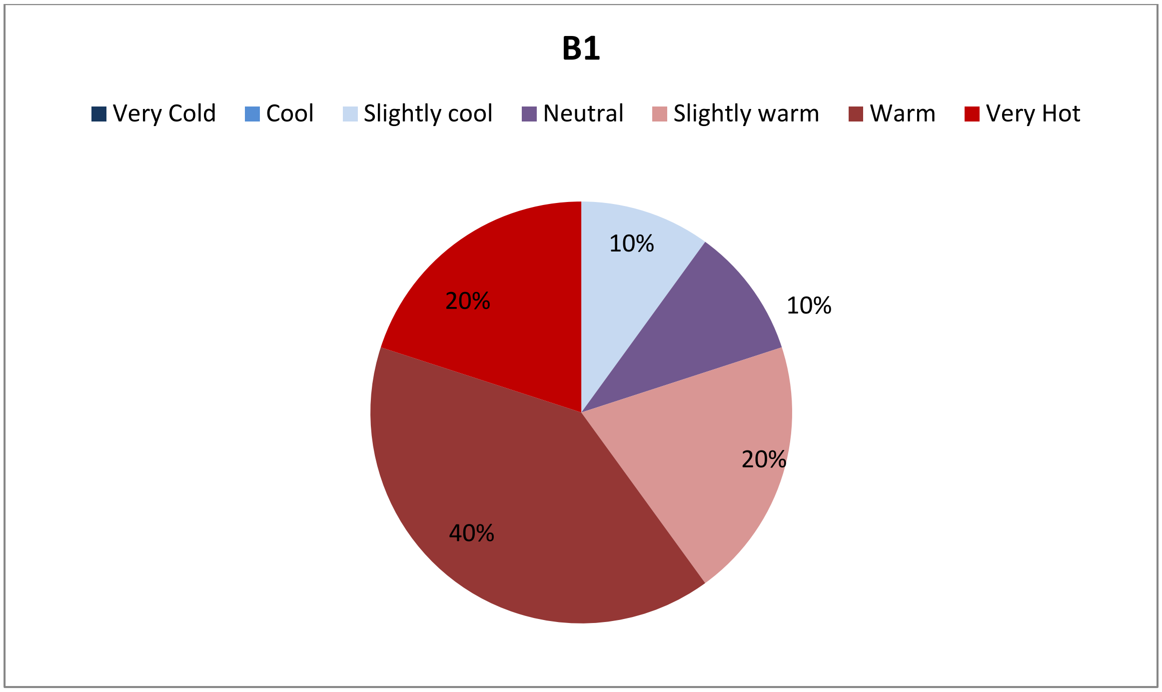


Figure 4.50 Students thermal sensation in classroom B1

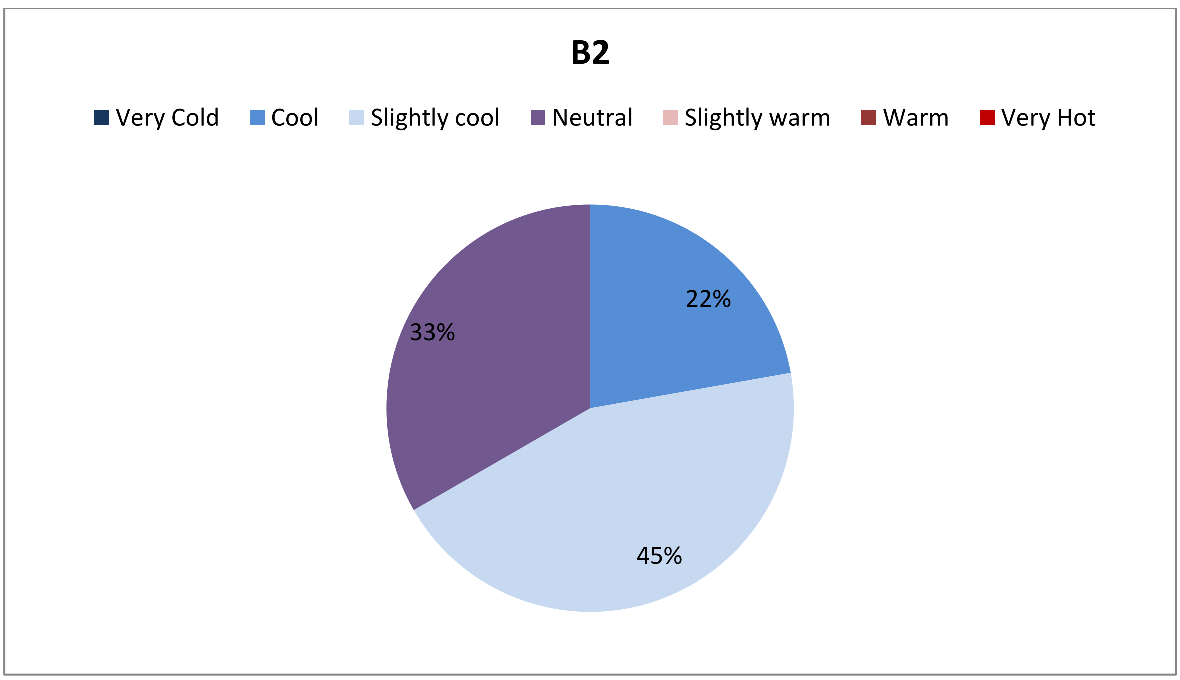


Figure 4.51 Students thermal sensation in classroom B2

Figure 4.52 and 4.53 represents the satisfaction levels of students with the thermal environment of their classroom. The satisfaction level of the occupants with thermal conditions of classroom B1 demonstrated that only 15% of the respondents evaluated the indoor climate as fairly acceptable and 45% votes stated neutral. Others votes for slightly unsatisfied (20%), unsatisfied (20%). These dissatisfaction scales can be corresponded to a majority of votes of slightly warm, hot and very hot for the thermal sensation. Classroom B2 responses to the indoor thermal environment was very different compared to classroom B1 since distribution of the thermal comfort satisfaction vote demonstrated that more occupants are satisfied than dissatisfied. Subject's votes were as follows: very satisfied (39%), satisfied (44%), fairly acceptable (6%) and neutral (11%). Although their thermal sensation votes were mostly in cool side of the scale (22% cold, 45% slightly cold), but generally they felt thermal environment was satisfactory. All occupants of classroom B2 wore only two layers of clothing upper and lower halves of the body, so average of the clothing insulation level was the lowest compared to all other studied classrooms.

Students' responses in school B indicated that indoor climatic conditions in classroom B1 (39 %, 24.5 °C, 4.7 m/s) did not fall within the majority of the occupants' comfort boundaries. On the other hand, classroom B2 indoor climatic conditions (41 %, 23 °C, 5.8 m/s) did fall well within the occupants' thermal comfort zone. Results of classroom B2 probably demonstrated that fewer layers of clothing, lower indoor temperature and higher air speed result in a more comfortable situation compare to classroom B1.

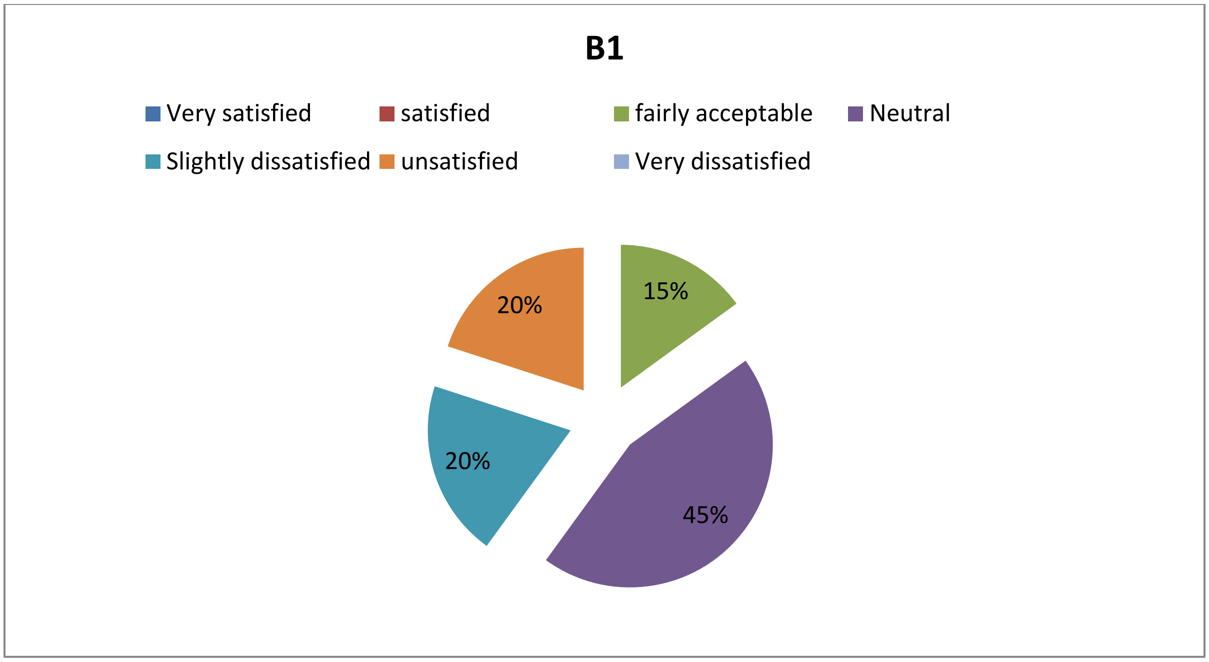


Figure 4.52: Students satisfaction response to indoor physical parameters (temperature, humidity, air speed) in classroom B1

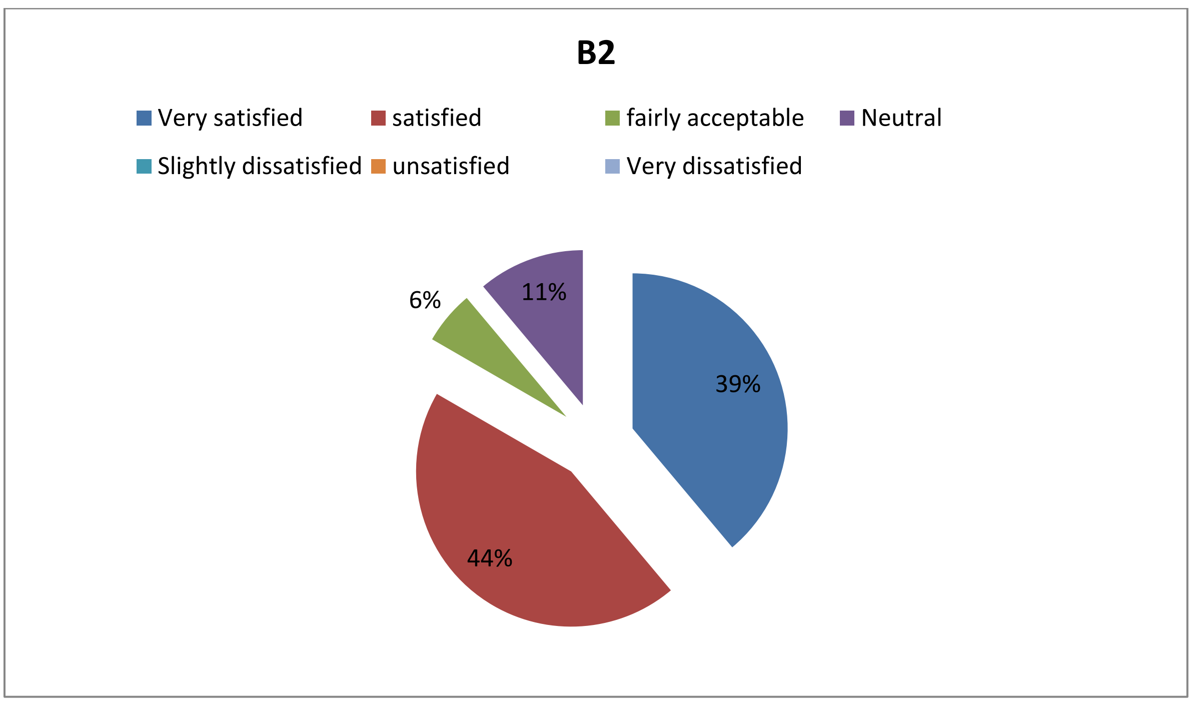


Figure 4.53: Students satisfaction response to indoor physical parameters (temperature, humidity, air speed) in classroom B2

Figure 4.54 and 4.55 revealed that the number of students who suffered from physiological health symptoms in classroom B1 and B2. A diverse range of respondents (e.g. different age, socio-economic background) in school B had health problems that may raise the susceptibility to indoor air pollution.

Many students in classroom B1 were allergic to dust (45%) or they had eczema problem (40%) and some students in classroom B1 had asthma (20%). Quite a few numbers of the occupants had health problems. Classroom B1's teacher had migraine and an allergy to dust. Those who had a health condition problem were more sensitive to indoor air contaminants compared to healthy occupants.

The most common health symptoms among students of classroom B1 were dry or itchy skin (30% of the respondents) and had difficulty in remembering or concentrating (30%). Other reported physiological symptoms were sneezing (20%), dry or irritated eyes (15%), headaches (10%), sore or dry throat (10%) and unusual fatigue (20%). Allergic and asthmatic subjects report symptoms more often. All respondents stated that they experienced symptoms few times per week in the previous 4 weeks. According to interview made with students and teacher, most of the reported symptoms were disappeared once the students had left the school. The teacher also suffered from headaches, nervousness and unusual fatigue for majority of last four weeks. When she is away from school, her unfavourable symptoms were gone and she felt better.

The occupants of classroom B2 who have problematic health conditions were fewer compared to classroom B2. Only one person was particularly sensitive to the presence of chemicals in the indoor environment of classroom B2. The most common reported health problem was allergy to dust (17%) and eczema (17%). Just a few students suffered from asthma (11%). Information collected about the health symptoms in classroom B2 demonstrated that every respondent who suffered from a health condition was more likely to experience sneezing and coughing a few times during the last four weeks.

Around 56% of the students experienced sneezing and 33% of them experience coughing. Other widespread reported health symptoms were dry or itchy skin (39%), difficulty in remembering (17%) dry or itchy eyes (17%), tension or irritability (11%), pain or discomfort (22%), and stuffy or runny nose or sinus congestion (11%). Students experienced majority of mentioned symptoms 1 to 3 days per week in last 4 weeks. The majority of mentioned symptoms went away as students left the school. The teacher of classroom B2 was allergic to dust and also suffered from headache, sore or dry throat, tired or strained eyes, sneezing and dry skin while she was in school environment. She suffered from mentioned symptoms 1 to 3 days in the last week

The teacher of classroom B1 and B2 also used the printer, photocopier and odorous chemicals (e.g. glue, markers, spray, and cleanser) 3 to 4 times a week. Therefore, some of the activities could put them at a higher risk and may raise her vulnerability to the indoor air pollutants of classroom. Reported symptoms can be a result of high levels of pollutants in ambiance air of selected classrooms in school B. The indoor level of carbon dioxide was high in classroom B1 and B2. In addition, classroom B2 had a very high concentration rate of TVOCs among all studied the classrooms because of the excessive use of indoor air freshener products.

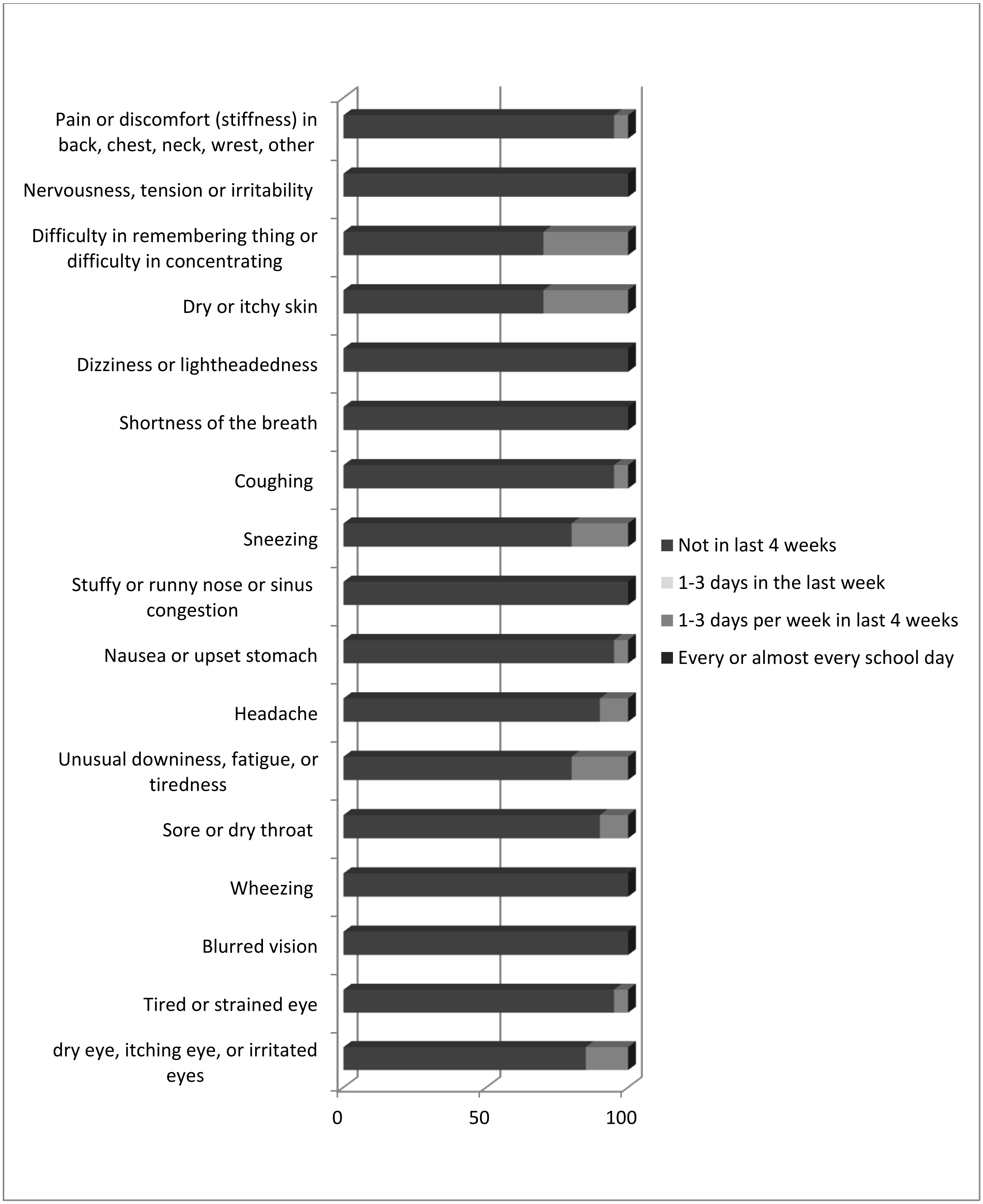


Figure 4.54: Physiological Symptoms in Classroom B1

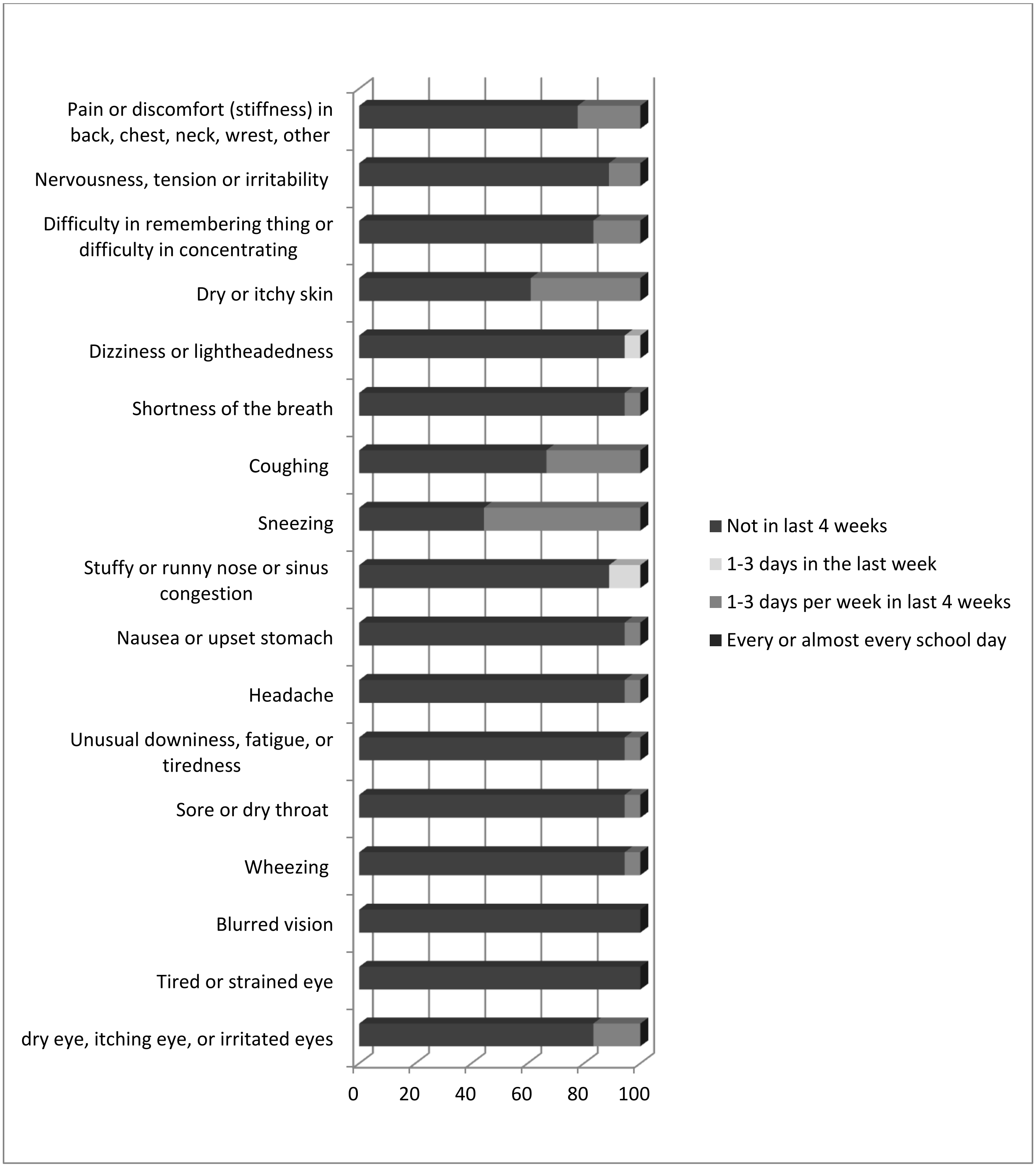


Figure 4.55: Physiological Symptoms in Classroom B2

4.3.3 School C

The survey was carried out in the morning between 8:40 and 9:40 a.m. in classroom C1 and between 8:10 and 9:15 a.m. in classroom C2. During the surveying time in classroom C1 three mechanical systems were used for modifying the indoor air and the doors had been opened many times. Throughout the survey in classroom C2 one of the mechanical systems had not been used (turned off) and the door had been closed for the majority of the time (the door had been opened only a few times for a very short period of time). Eighteen students from classroom C1 and seventeen students from classroom C2 had completed the survey questionnaires. The age range of the students was between 7 and 11 years. The average age of the students in the selected classrooms was 9. Figure 4.56 and 4.57 present distribution of thermal sensation votes for the students in classroom C1 and C2 respectively.

The average of indoor physical parameters in classroom C1 during the survey wore as follows: indoor temperature is around 23.5 °C, the humidity was around 44.5% and the indoor air speed was 5.4 m/s. Students of classroom C1 voted for warm, slightly hot, neutral, slightly cold, and cold with a distribution level of 16%, 21%, 32%, 21% and 10% respectively. Their teacher voted for neutral and felt generally that the thermal parameters were fine. It was observed that votes were mainly distributed between the slightly hot, slightly cool and neutral sections. Only two occupants felt cool (cold) and 3 occupants felt warm in the indoor environment of classroom C1. The students' response to thermal preferences revealed that 72% of them did not want any change to their indoor environment, whilst 17% wanted cooler indoor temperatures and 11% wanted a warmer classroom. 66% of the students and their teacher stated that the indoor air movement was acceptable. 17% of the student's claimed that indoor air movement was not enough (too little) and 17% students reported that there was too much indoor air movement (speed). All the students and the teacher perceived humidity levels of the indoor environment as acceptable (normal).

School C had a special uniform as a dress code. Their uniform consisted of short sleeved blouse (cotton) and full length trousers made of cotton. Students were able to add extra layers of clothing whenever they feel cold. Some students were observed wearing jackets during the investigation. About 95% of the students wore 2 layers of clothing on the upper half of their body; only 5% of them wore one layer of clothing in the upper half of their body. 33% of students claimed that they felt more comfortable by adding or removing a layer of clothing. 22% of the occupants wore 3 layers of clothing; 61% wore 2 layers of clothing and 17% wore only one layer. All respondents who felt cold or warm were among those who want to adjust their clothing. Throughout the survey students' activity level was low and garment insulations had a fine concurrence with students heat balance to surrounding atmosphere.

While the survey was conducted in classroom C2, average of the indoor temperature was around 26.5 °C, relative humidity was around 44 % and indoor air speed was 4.2 m/s. It is apparent from figure 4.57 that no one in the classroom C2 felt cold or very cold. Students of classroom C2 voted for very hot, hot, slightly hot, neutral and slightly cold with a distribution of 6%, 12%, 29%, 35% and 18% respectively. About 53% of the students favoured to make the room cooler and 47% wanted no change. 71% of the students perceived that the humidity level was acceptable whilst 19% of the respondents perceived that the air as too dry. 76% of the occupants felt the indoor air movement was acceptable, whilst 23% felt that the indoor air speed was too little. Teachers of classroom C2 voted for neutral in the thermal setting scale of classroom C2 and felt all current environmental physical parameters were in an acceptable range, but mentioned one to three days in the last week, the indoor temperature was very hot.

11% of the occupants believed by opening the window they could achieve comfort, while 24% believed they could achieve thermal comfort by getting closer to air conditioning system. 35% assumed by turning on all 3 of the mechanical systems they could achieved preferable thermal setting. Adjusting the layers of clothing for 29% of students was an ideal activity to achieve comfort. 71% of students wore 2 layers of clothing in the lower half of their body, whilst 20% wore only one layer of clothing. 76% of students wore 2 layers of garments in upper half of their body, 6% wore one layer, and 18% wore 3 layers of clothing. The teacher wore 3 layers of clothing on her upper half and 3 layers on her lower half of her body. In general, the average level of insulation of the students' garments was not high in classroom C2.

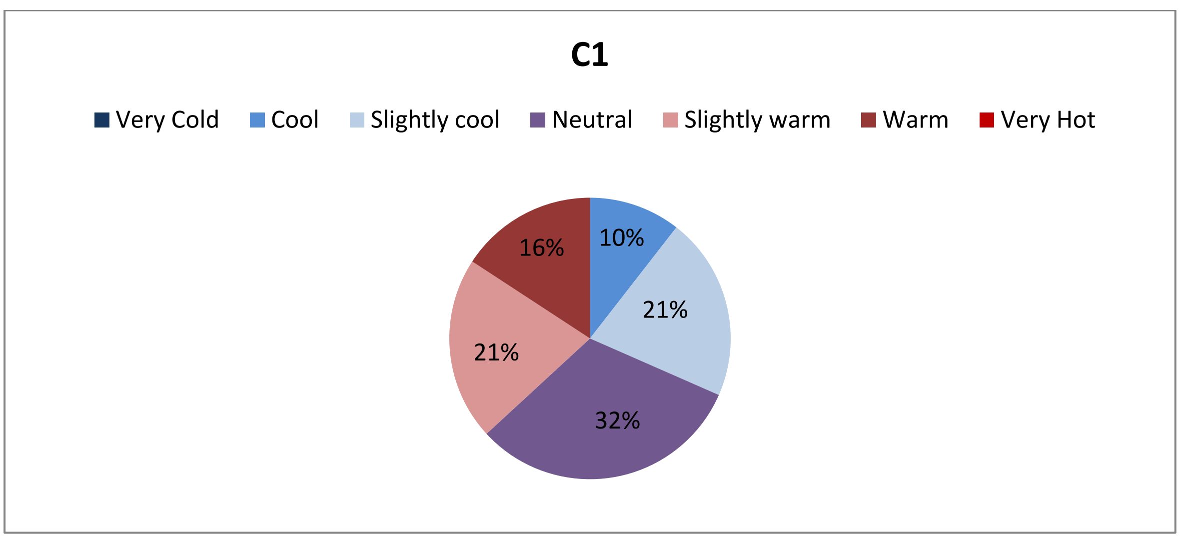


Figure 4.56: Distribution of Students' Thermal Sensation Votes in Classroom C1

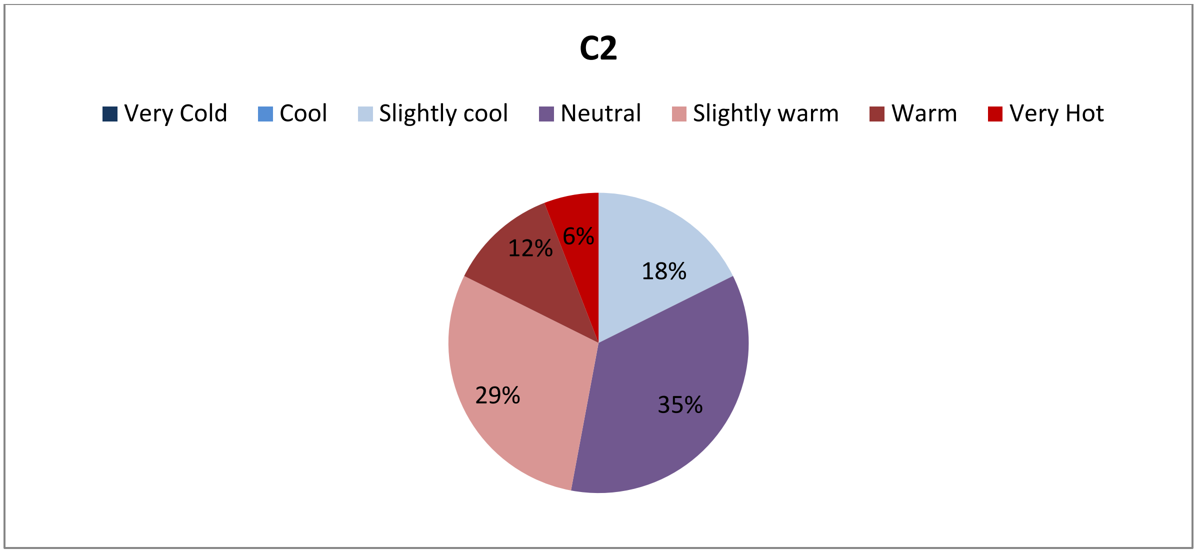


Figure 4.57: Distribution of Students' Thermal Sensation Votes in Classroom C2

Distribution of the satisfaction level of the students in classroom C1 was demonstrated in figure 4.58. 12% of the respondents in classroom C1 voted for very satisfied; 23% voted for satisfied; 35% percent voted for fairly acceptable; the number of people who voted for fairly acceptable and felt slightly cool was superior than those who felt slightly warm, though the percentage of both sensations were alike. The majority of the subjects, who felt cold or warm, voted for neutral on the satisfaction scale. Thus, they felt more or less comfortable with the thermal setting of the room and they felt the thermal setting of the room was in an acceptable range. Only 6% of students were slightly dissatisfied; thus, the majority of occupants felt comfortable with the indoor environment of their classroom. Classroom C1 has the highest rate of satisfaction vote among male students' classrooms. More than 70% of votes are distributed within central three category of thermal sensation scale, so it was predicted that majority of students were comfortable.

Distribution of 'satisfaction' votes by the students in classroom C2 is demonstrated in Figure 4.59. Classroom C2 climatic condition (44 %, 26.5 °C, 4.2 m/s) was different than classroom C1. It has highest indoor temperature compared to other investigated classrooms. Distribution of students' satisfaction votes in classroom C2 was slightly shifted in the direction of the satisfied side of the scale, even though thermal sensation votes skewed in warm side of the scale. 23% percent of occupants voted for neutral in thermal satisfaction scale. 35% voted for fairly acceptable and 12% percent voted for satisfied. Only 24 % of respondents voted for slightly dissatisfied and 6% for unsatisfied. The mentioned figures demonstrated that many occupants felt the classroom thermal condition was satisfactory. Students gradually got used to a slightly higher temperature (26.5 C) since they had been experiencing similar circumstances or even hotter indoor temperatures recently. Either the proper level of garment insulation or adaptation of student's body to presented thermal setting (slightly high indoor temperature) can be corresponded to them accepting the thermal environment.

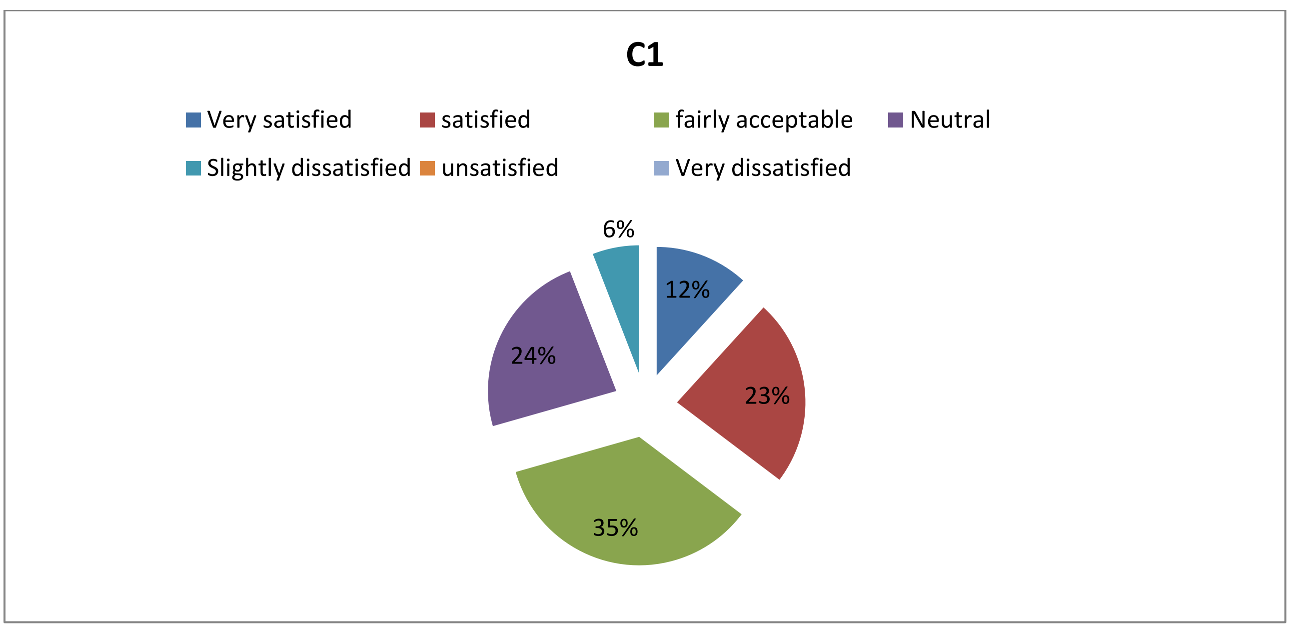


Figure 4.58: Students satisfaction response to indoor environment (physical parameters: temperature, humidity, air speed) in classroom C1

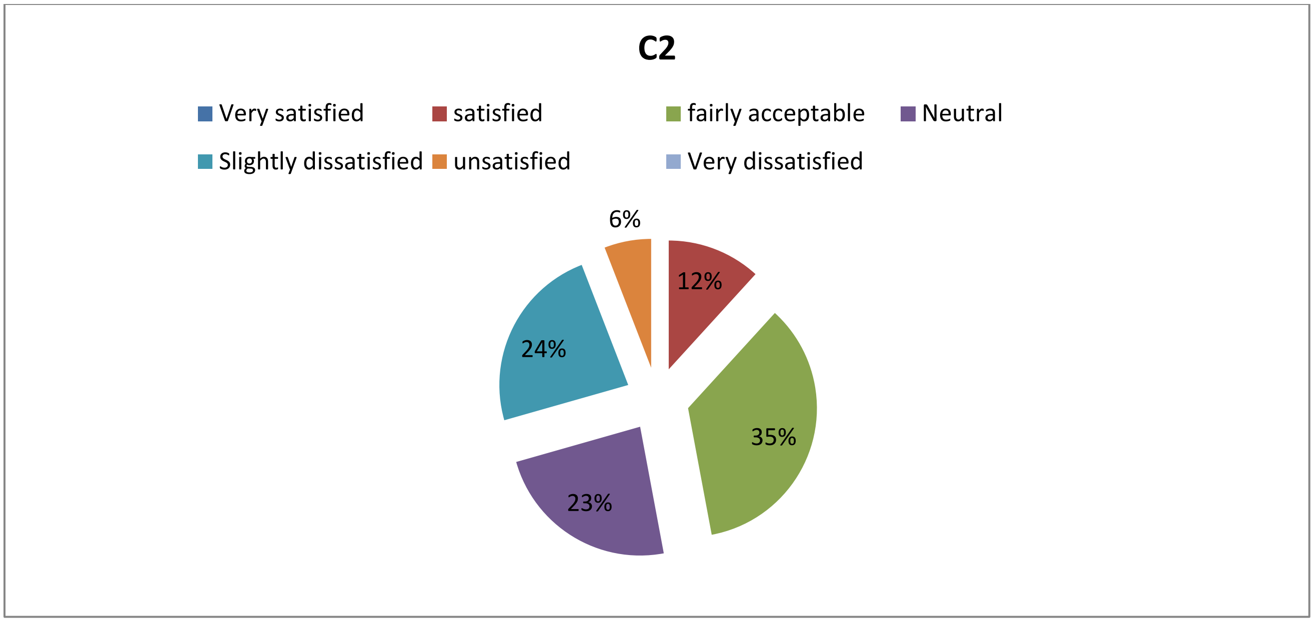


Figure 4.59: Students satisfaction response to indoor environment (physical parameters: temperature, humidity, air speed) in classroom C2

Figure 4.60 displays the distribution of health symptoms of students in classroom C1. Among the 18 students of classroom C1, 22 % reported a doctor diagnosis of eczema and 22% reported a doctor diagnosis of asthma. About 6 % of students were diagnosed with allergy to mould, allergy to dust, and occasional migraines. However, the overall health status of students' in classroom C1 was in a good condition but a few students with diagnosed health problems suffered from contaminated indoor air. The most common complaints among students were; sneezing (39%) followed by dry or itchy skin (17%), headaches (11%), nervousness (11%) and dry or irritated eyes (11%). Other symptoms had a very low complain rate. The majority of students declared that they experienced symptoms a few times per week in the last four weeks and the symptoms are gone as they were away from school. Only one of the students declared that he had suffered from tired eyes for majority of the school days. He also suffered from sneezing and wheezing a few times a week. He most likely was one of the hyper sensitive individuals who were very susceptible to indoor pollutants. The teacher of classroom C1 reported a doctor diagnosis of migraine and an allergy to dust. She suffered from headaches, dry or itchy skin and nausea for majority of school days. She mentioned that all unfavourable symptoms disappeared or improved when she was away from school. The teacher of classroom C1 and C2 used the photocopying machine and the chemical materials (e.g. glue) at least once a week. Those chemicals can pose a great risk to teachers' health condition.

Figure 4.61 displays distribution unfavourable health problem of the students in classroom C2. Among the 17 students, 12% reported a doctor diagnosis of eczema and 18% reported a doctor diagnosis of asthma. About 6% of students were allergic to dust and mould. Generally, the students looked very healthy, strong and active. The most common complaints among students' of classroom C2 was itchy or dry skin (18%) and nervousness (18%). Other common symptoms were difficulty in remembering things or concentrating (12%) and sneezing (12%). Most of the mentioned symptoms occurred 1-3 days per week in last 4 week. Classroom C2 had the lowest complain rate (from symptom) comparing to the other studied classrooms. Since only few students experienced the mentioned symptoms. The majority of students with health conditions suffered from asthma or eczema and also complained about itchy and dry skin. They experienced their symptoms almost every day during the past four weeks. The teacher of classroom C2 was in good health, only suffering from occasional headaches, pain or discomfort a few times in the previous week. Generally she felt fine after she left the classroom.

The overall number of students who complained about health symptoms in School C was low. However, the indoor air was highly polluted due to chemical contaminants such as CO, TVOCs, and other particulate matters. The school building was located on the main road and in an area with high traffic rate; therefore, a high complain rate from physiological symptoms was expected, but the survey outcome demonstrated that the majority of students were in good health.

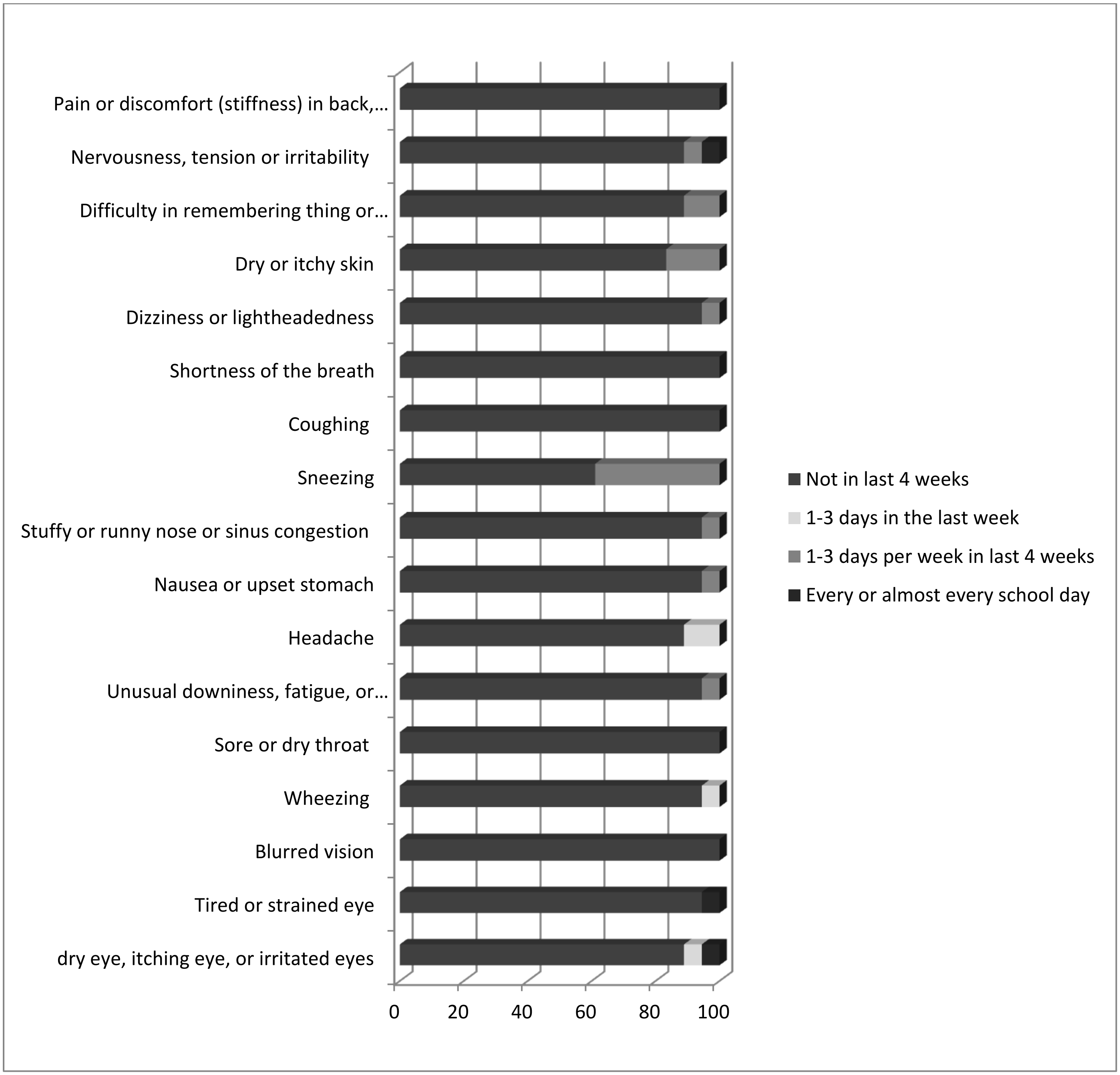


Figure 4.60: Distribution of Physiological Symptoms in Classroom C1

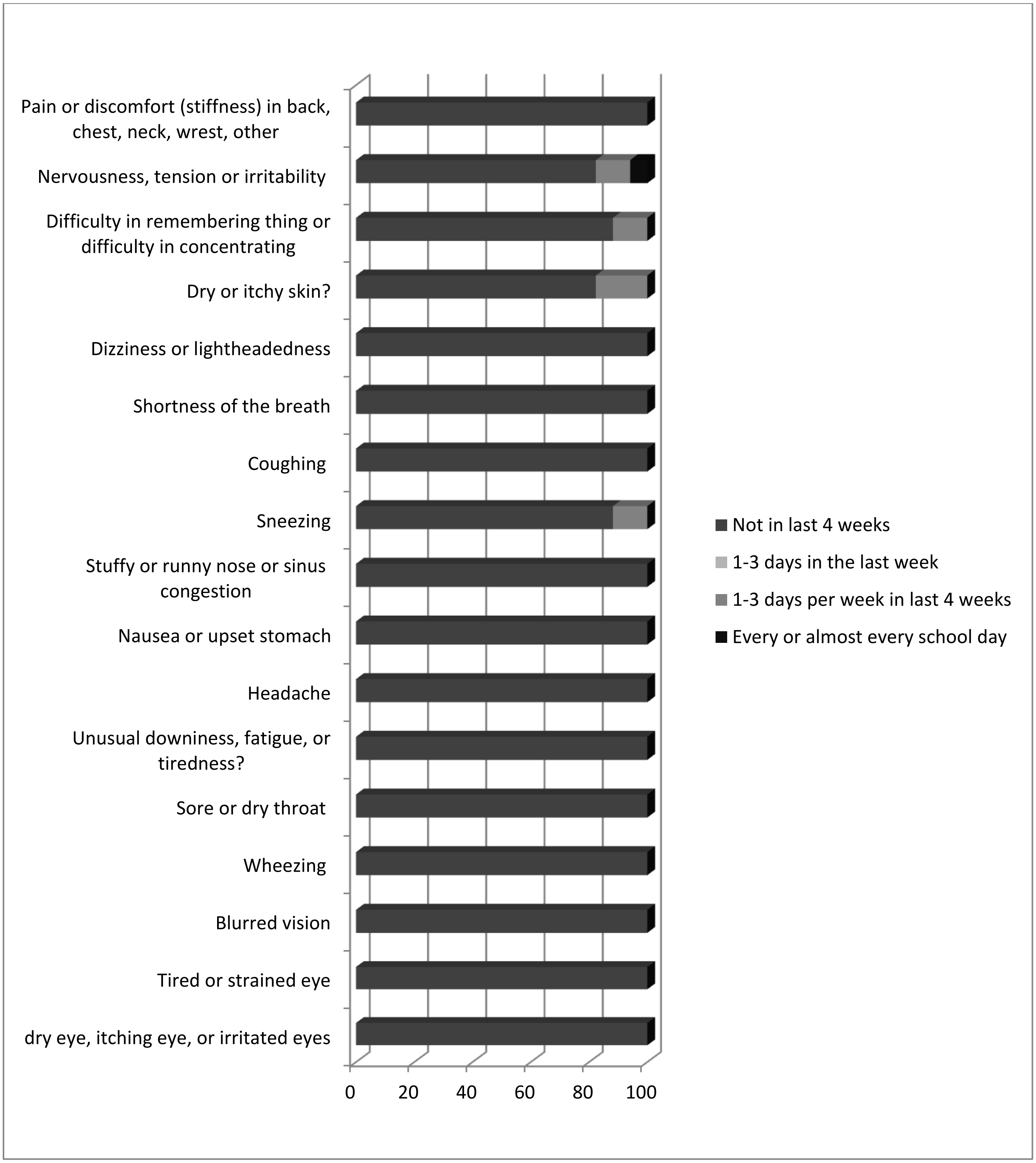


Figure 4.61: Distribution of Physiological Symptoms in Classroom C2

4.3.4 School D

The survey was conducted in the morning between 8:30 and 9:20 a.m. in classroom D1 and 8:15 to 9:05 a.m. in classroom D2. Throughout the time classroom D1 and D2, the mechanical systems were used for regulating the indoor air. The classrooms' door had been opened at the beginning (between 8:30 to 8:50 a.m. in classroom D1 and between 8:15 to 8:50 a.m. in classroom D2) of the survey, but for the rest of surveying period the door had been mostly closed. Eighteen students from classroom D1 and seventeen students from classroom D2 had completed survey questionnaires. Students' age in selected classrooms in school D was between 8 and 13 years old. The average age of the students in the selected classrooms was 9 years old. Figure 4.62 and 4.63 shows the distribution of students' thermal sensation votes in classroom D1 and D2 respectively.

During the surveying period of classroom D1 the average indoor temperature, relative humidity and air speed were as follows: 21 °C (20.7°C), 35% and 3.8 m/s. The majority of respondents' votes are within central three categories. Students of classroom D1 voted for slightly warm, neutral and slightly cold with a distribution of 39%, 50%, and 11% respectively. About 72% of students felt the temperature was fine and they voted for 'no change'. 17% of the students wanted the room to be cooler and 11% wanted the room to be warmer. Humidity levels of the classroom was perceived as 'too dry' by 17% of students, while 83% of students perceived humidity of classroom as acceptable. The air speed within the classroom was perceived as acceptable by 78% of students. About 16% of the respondents felt the indoor air speed was 'too little'; whilst 6% of students felt the air speed is 'too much'. All who voted for a slightly warm indoor temperature perceived the indoor air speed as "too little". The teacher of classroom D1 felt neutral with thermal setting of the classroom, but preferred a cooler indoor environment. The teacher felt that the air movement and the humidity level were in an acceptable range.

School D had a very similar dress code to school C. 56% of students wore two layers of clothing on upper half of their body. 22% of occupants wore 3 layers of clothing on upper half of their body, while the rest wore only one layer of clothing. 72% of subjects wore two layers of clothing in lower half of their body. 17% of the occupants wore four layers of clothing on the lower half of their body, while 11% wore only one layer of clothing on the lower part of their body (without consideration for shoes and socks). The teacher wore 3 layers of clothing on the upper and 2 layers on the lower half of her body. Though, the average layer of clothing in classroom D1 was not high but 33% of occupants selected adding or removing a layer of clothing as an ideal activity for achieving thermal comfort. This figure may indicate that the maximum level of clothing should not exceed two layers.

During the surveying period in classroom D2, the average indoor temperature, relative humidity, and air speed were as follows: 18°C, 42% and 3.8 m/s. Distribution of the thermal sensation votes showed a higher frequency towards the cooler end of the scale. Students of classroom D2 voted for very cold, cold, slightly cold, neutral, and slightly warm with a distribution of 6%, 29%, 24%, 35% and 6% respectively. Their teacher voted for neutral sensation in thermal sensation scale. About 71% of the students mentioned that the indoor temperature was fine and they did not want any change, while 12% preferred to make it warmer, and 11% preferred to make it cooler. Majority of students (88%) and their teacher perceived humidity level as ‘acceptable’. The teacher and 18% of students’ of classroom D2 felt too little air movement within classroom environment, while 82% of young subjects perceived indoor air movement as ‘acceptable’. About 88% of students wore two layers of clothing in upper and lower halves of their body and 12% of students wore one layer of clothing in upper and lower halves of their body.

Figure 4.64 shows the distribution of thermal satisfaction votes for students of classroom D1. Since the majority of students voted for the central three categories in thermal sensation scale, it was expected that the subjects were comparatively satisfied with the thermal condition, but figure 4.63 demonstrated that 17% of the votes were in slightly dissatisfied categories. Therefore, it was apparent that there were a few students who voted within the central three categories and yet they did not feel the climatic condition of classroom was satisfactory. About 44% of students felt neutral about thermal environment of their classroom while 28% felt it was fairly acceptable, and 11% felt satisfied. The teacher of classroom D1 felt satisfied with the thermal setting of classroom D1. However, a few students did not feel the thermal environment of the classroom was acceptable, but the majority of the students and their teacher were comfortable with thermal environment of the classroom D1.

Figure 4.65 presents distribution of thermal satisfaction votes for students of classroom D2. Students of classroom D2 voted for very satisfied, satisfied, fairly acceptable, neutral, and slightly dissatisfied, with a distribution of 18%, 23%, 12%, 41% and 6% respectively. Their teacher felt satisfied with thermal environment of classroom D2. The majority of the occupants felt comfortable with thermal environment of classroom, though 35% of young subjects felt either cold or very cold.

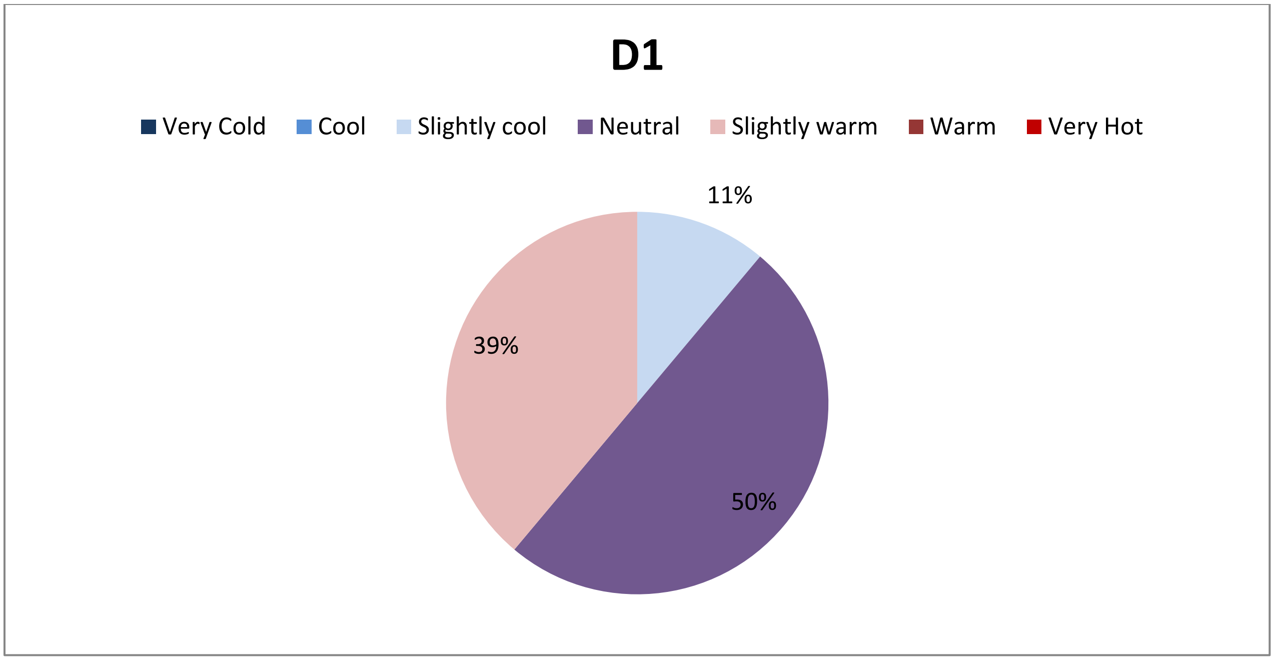


Figure 4.62: Distribution of students' thermal sensation votes in classroom D1

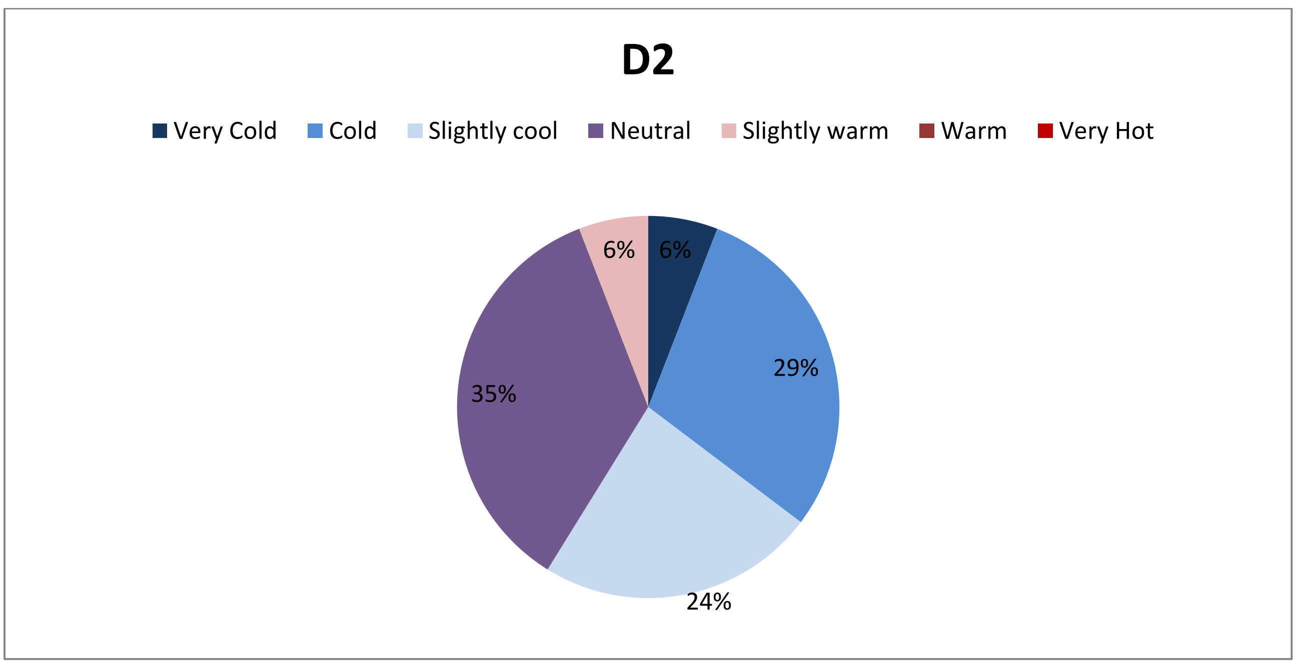


Figure 4.63: Distribution of students' thermal sensation votes in classroom D2

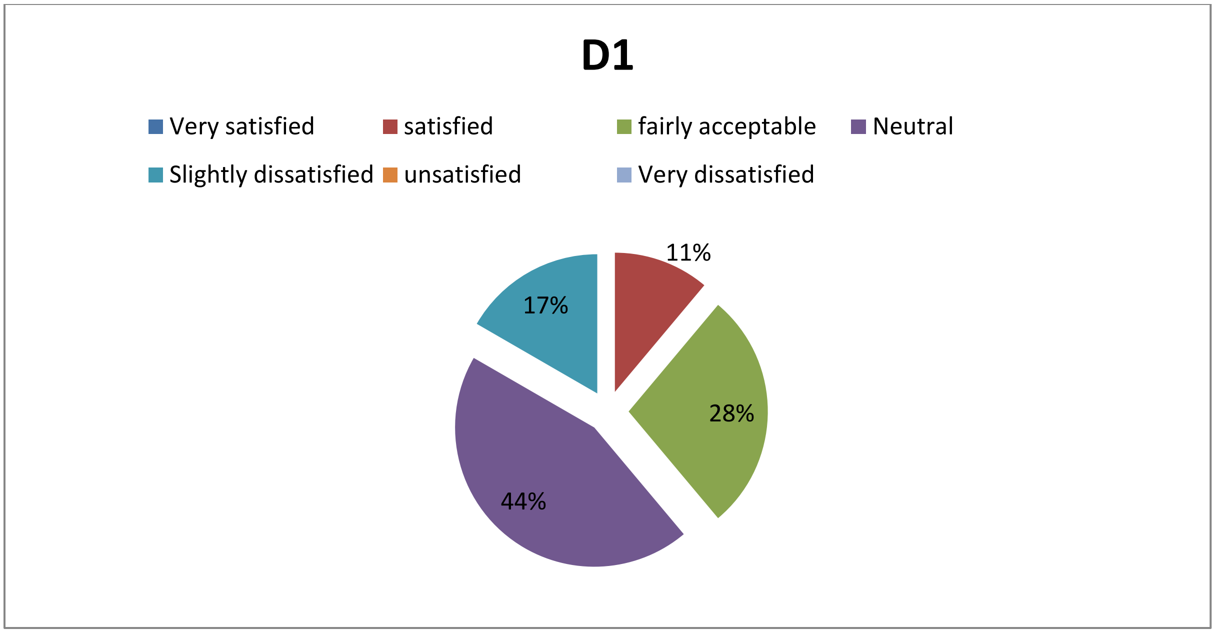


Figure 4.64: Distribution of students satisfaction vote with indoor environment (physical parameters: temperature, humidity, air speed) in classroom D1

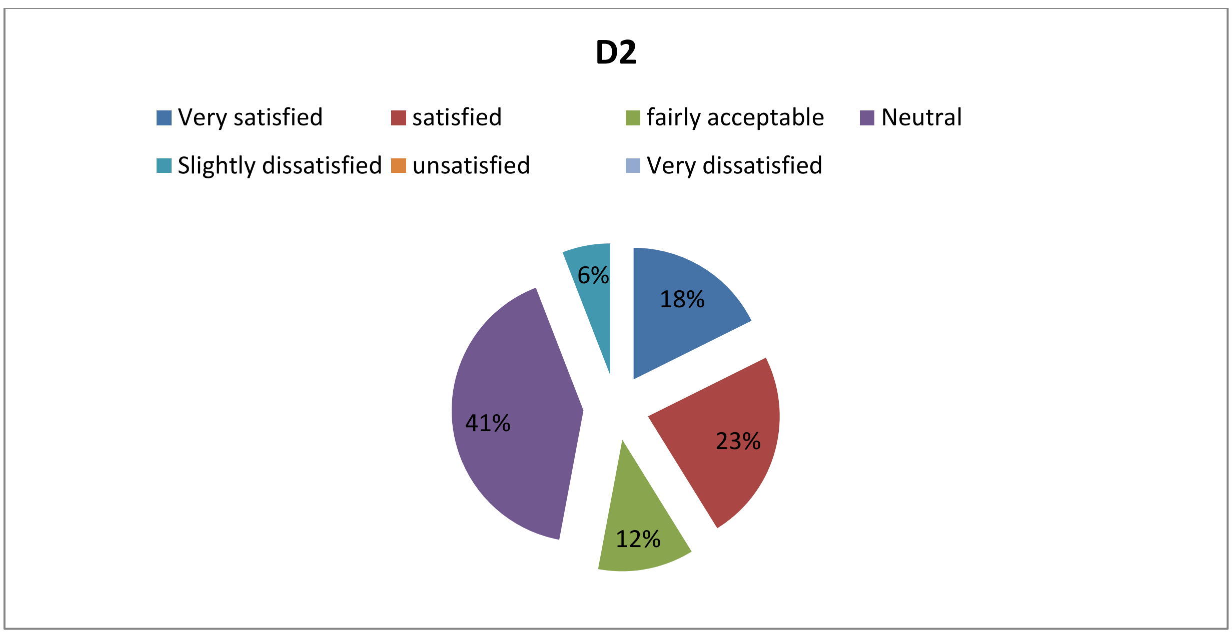


Figure 4.65: Distribution of students satisfaction vote with indoor environment (physical parameters: temperature, humidity, air speed) in classroom D2

Among the 18 students of classroom D1, 38% reported to be allergic to dust and 11% reported a doctor diagnosis of asthma. About 17% of the students reported to have an eczema problem and 6% reported to be allergic to mould.

Classroom D1 had the highest average indoor value of carbon dioxide between selected classrooms. Indoor measured values of carbon dioxide were generally very high; hence, the ventilation system of classroom D1 could not effectively reduce the concentration level of indoor air pollutants (not enough fresh air). Polluted indoor air probably increased the risk of asthma attacks, eczema problems and allergy reactions. Figure 4.66 shows the distribution of physiological symptoms in Classroom D1. The most common complaint symptoms among students' of classroom D1 was itchy or dry skin (22%) and sneezing (33%) for few days per week during the previous weeks.

Other symptoms were coughing (17%), unusual fatigue (17%), and difficulty in remembering and concentrating (11%). The remaining symptoms did not have a major number of complaints. Almost all reported symptoms disappeared after the students left the school environment. The teacher of classroom D1 suffered from tired eyes, blurred vision, unusual drowsiness, and coughing almost every day during the past 4 weeks. In addition the teacher suffered from pain or discomfort during one to three days in the previous week.

Among 17 students of classroom D2, 29% reported a doctor diagnosis of eczema problem and 35% reported a doctor diagnosis of asthma. About 18% of the students reported to be allergic to mould, 23% reported to be allergic to dust and 5% reported to suffer from migraine.

Therefore, the number of students who were at a higher risk and more vulnerable to indoor air contaminants was more considerable in classroom D2 compared to the other studied classrooms.

Figure 4.67 shows distribution of physiological symptoms in Classroom D2. 23% of students experienced dry or itchy skin 1 to 3 times per week during the four previous weeks and 12% experienced it almost every day whilst they were in schools. Thus, about 35%of students in classroom D2 experienced dry or itchy skin. 35% experienced sneezing one to three days per week during the previous four weeks. Distribution of sneezing problem was similar to dry or itchy skin. 24% experienced difficulty in remembering thing or difficulty in concentration 1 to 3 days per weeks during the previous weeks. 24% experienced tired eyes few times per week throughout the last previous four weeks. Other prevalent symptoms were unusual fatigue (12%) coughing (12%) and pain or discomfort (12%). Remaining symptoms did not have a major number of complaints. Majority of reported symptoms were gone as students left the school. The teacher of classroom D1 suffered from unusual drowsiness, headaches, and dizziness at least one to three days in the last week. The teacher also mentioned that she felt better whilst she was not in the school environment. Teachers of classroom D1 and D2 declared that they use odorous chemicals and the photocopier more than 3 times per week. Thus, their activities put them at a greater risk of contact with hazardous chemicals. In general most of occupants in selected classrooms were pleased with the thermal environment of their classroom. Majority of respondents in selected classroom wore two layers of clothing in upper and lower halves of their body (without considering shoes and socks). However, most of occupants were satisfied with physical parameters of indoor environment, but contaminated indoor air caused some of them to suffer from various physiological symptoms.

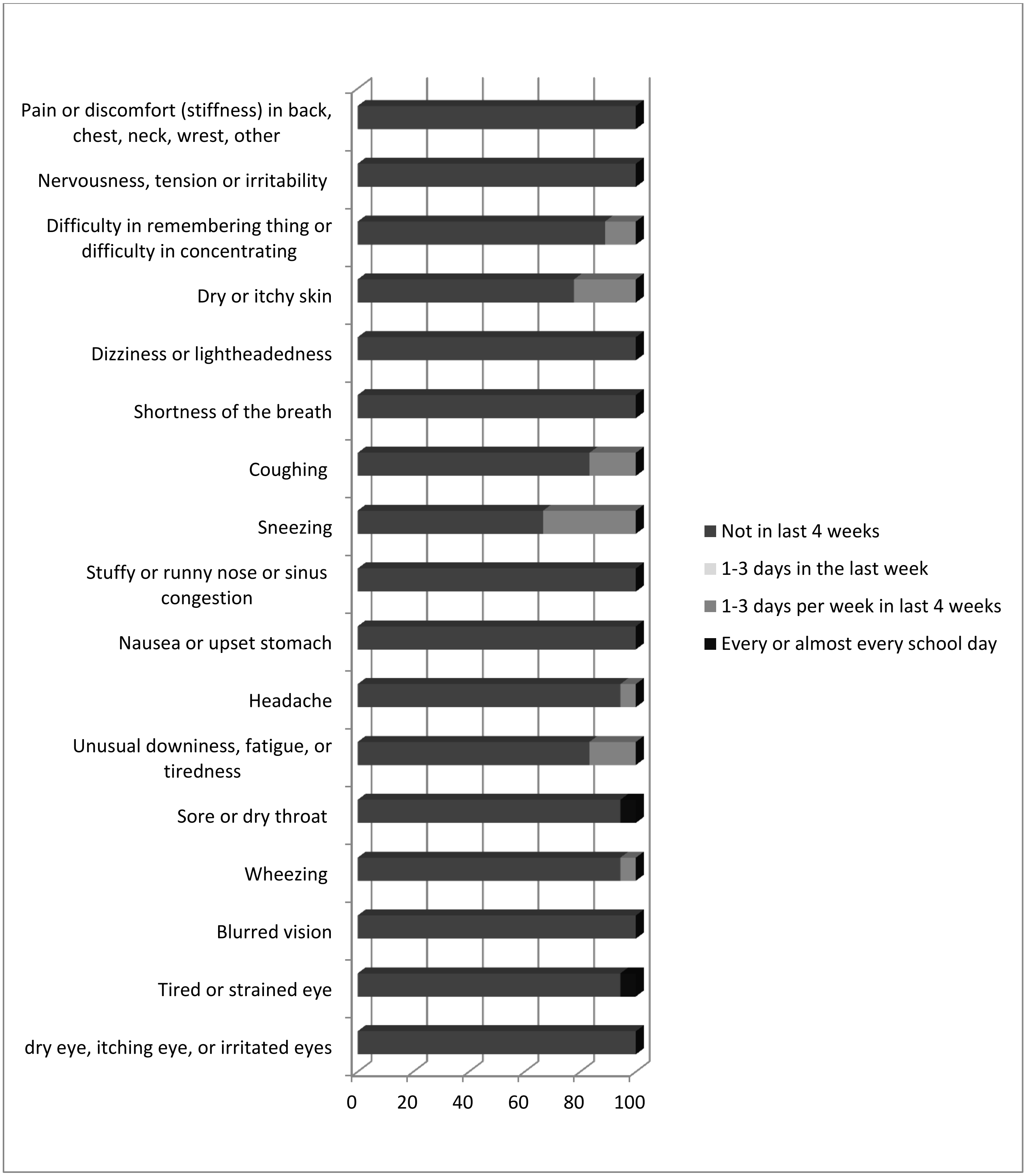


Figure 4.66: Physiological Symptoms in Classroom D1

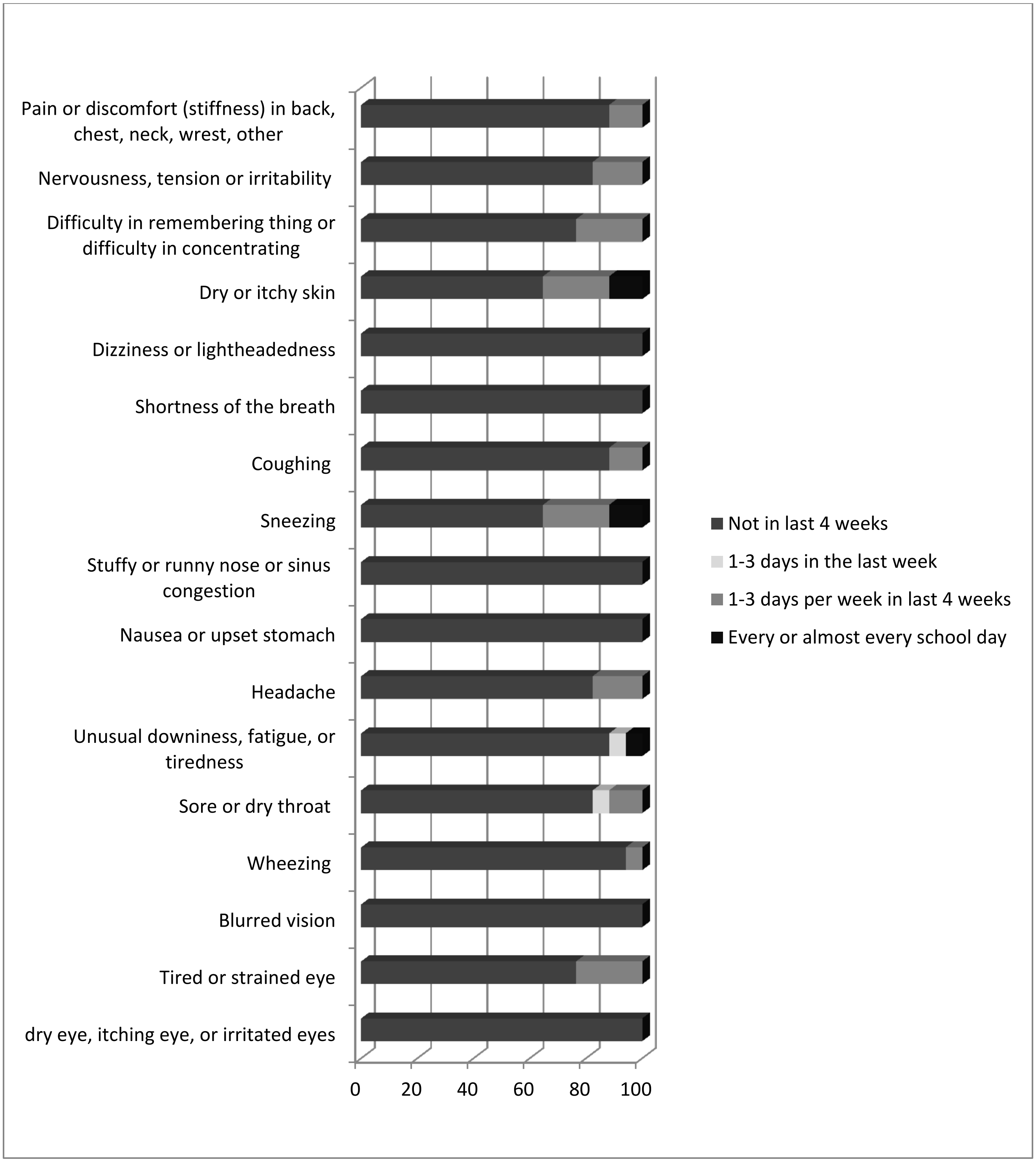


Figure 4.67: Physiological Symptoms in Classroom D2

Chapter 5: Discussion

5.1 IAQ

Normally in the majority of the schools, students spend less than 6 hours in their classrooms due to break times or particular subjects which require another indoor (e.g. music, English, art, science, sport hall) or outdoor space. Sometimes students of another class (similar grade) had lessons in the selected classroom; thus, the classroom was occupied by different students. Air pollution in the classroom can cause health risks not only for students of the particular class, but also for other users of the classroom.

Various factors impact IAQ in studied classrooms. These factors include inadequate or poor ventilation, outdoor activities that affect the fresh air coming into the school building (e.g. exhaust fumes from traffic and buses), inadequate maintenance and classroom cleaning. Specific contaminants like dust from construction (a huge amount in Dubai), fine particulate matters form vehicles (e.g. cars, school bus), and VOCs from cleaning supplies (particularly air fresheners) can be among main causes of poor IAQ. Outdoor air has a major impact on indoor air quality of classrooms. Schools which are located in a polluted area (near major road and high traffic density area) can have serious indoor air problems, if the ventilation system does not properly operate. Therefore, good indoor air quality can be achieved by proper building care, controlling the level of indoor air pollutant, and appropriate ventilation.

5.1.1 Carbon Dioxide

Different organizations suggest different limits for carbon dioxide concentration in the educational environment. According to EPA (2009b) and Daisey et al (2003) concentration of carbon dioxide in the indoor environment is usually used as a tool to measure whether the ventilation rate is sufficient. Indoor levels higher than 1000 ppm are usually considered as improper and indicate insufficient ventilation rates. The Department for Education and Skills (2006) declares that in all types of educational spaces average indoor concentration of CO_2 should not go beyond 1500 ppm. Pennsylvania Department of Health (PDH, 2011) and EPA (2009b) declare that unfavourable health symptoms can occur due to exposure to high concentration of carbon dioxide due to its asphyxiating properties. Carbon dioxide at concentrations greater than 15,00 ppm can cause some loss of mental capacity.

Carbon dioxide exposure level should not be higher than 5000 ppm. Carbon dioxide at a very high concentration is hazardous and can pose a health risk (Daisey et al, 2003). The carbon dioxide levels in the selected schools were below 5000 ppm. Concentration levels above 1000 ppm usually indicate that the ventilation rate in the room cannot sufficiently remove the level of body odour.

In the majority of classrooms the average concentration of carbon dioxide exceeds both (1000 or 1500 ppm) of the suggested limits. The average concentration of carbon dioxide in classrooms A1, A2, B1, B2, B3, C1, C2, D1,D2 were 863, 1238 1013, 1269, 811, 1034, 1492, 1593 ppm respectively. Classroom C1 in school C had the lowest average value of carbon dioxide.

According to Daisey et al (2003) indoor concentrations of CO_2 are linked with pattern of occupancy, time of the day and the rate of ventilation. The collected data from all selected classrooms (A1, A2, B1, B2, C1, C2, D1, D2) is consistent with angle's finding. For example, occupancy pattern in classroom A1 highly impact the indoor concentration of carbon dioxide since occupants are the main source of carbon dioxide production. The classroom was empty for the majority of monitoring time. The indoor levels of carbon dioxide for majority of monitoring time were in descending order whilst they were not in the classroom. The average concentration of carbon dioxide was below the threshold limit, but if the occupants were inside the room for majority of monitoring time the average concentration of CO_2 would have been much higher. ASHRAE/ANSI Standard-62.1-2010 states the unobjectionable outdoor level of carbon dioxide is approximately 300 ppm to 500 ppm. If the outdoor concentration is higher than the acceptable range (300- 500 ppm), it showed the elevated release of carbon dioxide from combustion sources. Hence, outdoor level of carbon dioxide in the school district was high. Classroom A1 was close to the main road and public parking. Elevated levels of carbon dioxide were probably caused by vehicle's fuel combustion. If the classroom had full occupancy for long period of time, the indoor value of carbon dioxide would increase and might reach a very high level, and then the ventilation system would not adequately dilute the level of contaminants.

The highest value of carbon dioxide was in school D. The main reason was the short distance (much less than 30 meters) between the classroom and school buses' loading/unloading area. The minimum distance between the school bus parking lot and the school building's ventilation should be 30 metres (Shendell et al, 2004a). Exhaust emissions from idling buses can enter the indoor environment of selected classrooms by natural or mechanical ventilation. The classrooms air intake vents were placed close to the bus loading/unloading area. Hence, the indoor air quality of the selected classrooms was probably contaminated. There is a need for modification of school buses' loading/unloading area in the school. In addition, unnecessarily idling of school buses should be minimized.

5.1.2 Ozone

Usually the main source of indoor ozone is outdoor air which is carried in by ventilation means. Therefore, outdoor ozone level can verify the variation of O_3 concentration in the classrooms. The WHO (2008) limits the ozone concentration level to 100 μg/m^3 (around 50 ppb) ppb for 8 hours exposure. Nolen and Shprentz (2010) declared that the ozone concentration level should not exceed the range of 60 to70 ppb for 8 hours exposure. The average concentration of ozone in classroom A1, A2, B1, B2, B3, C1, C2, D1,D2 were respectably 42, 48, 54, 40, 42, 54, 22, 14 ppb. School D had the lowest value of ozone concentrations compared to all the schools that were studied. This could indicate that the outdoor air in school D's region had low ozone level.

During the investigation periods in classroom C2 the outdoor weather was cloudy or rainy. However, there was not enough sunshine for photochemical ozone creation, but indoor ozone values were high. Thus, the air quality in the school neighbourhood was more polluted by ozone compared to other selected schools. School C was located close by a major highway with elevated traffic density. There is a need for further investigation on the ozone level in the district around School C.

The overall value of the ozone in some of the selected schools was between the acceptable ranges according to the guidelines. The intensity of physiological health problems caused by exposure to ozone is not only dependant on the length of the exposure or ozone concentration level, but also it relies on parameters such as wellbeing condition. Adverse health effects attributed to ozone exposure may differ widely between individuals. (GreenFacts, 2005; Imperial Valley Air Quality (IVAQ), 2010). Hence, exposure to low levels of ozone can cause health problems for some sensitive students in some schools.

5.1.3 Total Particulate Matter

However, TPM (Total Particulate Matter) cannot specify the percentage concentration of PM1.0, $PM_{2.5}$, and PM_{10}, but it can demonstrate the total amount of suspended particulates within the classroom environment. The standards for daily average limits of PM 10, PM2.5 in ambient air are 150 and 65 μg/m^3. Average concentration of Total Particulate Matter in classroom A1, A2, B1, B2, C1, C2, D1,D2 were 183, 160, 120, 102, 153, 136, 130, 157 μg/ m3 respectively.

There is no recommended guideline for indoor TPM but we can definitely state that the collected data from the classrooms indicated a high indoor value of total particulate matters. The indoor level of Total Particulate Matter (TPM) in classrooms was caused by outside and inside building pollutant sources. The floor dust in the classrooms, which is re-suspended in the air, mainly originated from the shoes of the occupants or from outdoor air entering the classroom.

Air pollution in the majority of Dubai's region during windy days is usually full of sand and dust particles (due to the climate and construction activity). In addition, exhaust fumes from vehicles produced fine particles that can pose a health risk. In all schools polluted outdoor air entered the environment of the classroom whenever the door was opened and impacted the indoor level of TPM. If the school is located in a district with high traffic rate by not opening the door during the high traffic hour or polluted hour, the contaminated outdoor air would impact the indoor air less.

It was observed that the selected classrooms (A1, A2, C1, C2, and D2) with floor carpets had higher concentration values of TPM. Dust and dirt particles sink down into the carpet fibres. Whenever the students played or sat on the carpet, dirt particles and dust float in the air.

School B had the lowest values of TPM compared to other studied schools. However, the external parts of the air conditioning systems in school B were covered with dust and dirt; in addition some indoor surfaces were covered by dust. Thus, the outdoor air was probably less contaminated with TPM compared to other schools. The main sources of TPM were dust and dirt on mentioned surfaces which affected the performance of the mechanical system and the indoor level of TPM. Appropriate cleaning of the room and more frequent and proper maintenance of mechanical system can reduce the indoor level of TPM.

5.1.4 Carbon Monoxide

ANSI/ASHRAE Standard 62.1-2004 and EPA recommend that CO exposure should not exceed the limit of 50 ppm (50000 ppb) for 8 hours duration. Average concentration of carbon monoxide in classroom A1, A2, B1, B2, B3, C1, C2, D1,D2 was 1958, 1483, 1333,1813, 1118, 1425,673, 902 ppb respectively. Overall average concentration and maximum concentration of CO in selected classrooms were much lower than the recommended limits.

The highest average value of carbon monoxide was for classroom A1. During the time the public parking area was very crowded the indoor level of carbon dioxide increased as the outdoor air entered the room by means of natural ventilation. High outdoor level of carbon monoxide which impacted the indoor level was perhaps caused by unnecessarily idling of vehicles in public parking lot. Public awareness about health impact of carbon monoxide may positively influence drivers to reduce idling time and help the schools.

School D has the lowest average of carbon monoxide, but even that low level of carbon monoxide which was mainly caused by exhaust fumes from school buses. It was noted that the outdoor air in School D’s neighbourhood was the cleanest among the studied schools. This may be caused by huge Public Park close to the school and low density residential districts. The average amount of green landscape around the school area was higher than all other studied schools. The main problem in school D was location of the school buses’ loading/unloading area. In addition, the mechanical ventilation of the selected classroom probably could not provide good quality air. The problem could be fixed by more frequent maintenance of air conditioning systems since proper maintenance of air conditioning system occurred only twice a year.

5.1.5 HCHO and TVOCs

There are different guidelines for maximum exposure limit to formaldehyde concentration in the indoor environment. NIOSH suggests 0.016 ppm for 8 hours exposure to formaldehyde (Zhang et al, 2009)**,** and the Office of Environmental Health Hazard Assessment (OEHHA, 2000) recommends 23 ppb. In all the selected schools, the concentration of formaldehyde was lower than 0.01 ppm. Some studies indicate that frequent or long term breathing of formaldehyde at concentration of 0.002 ppm can adversely impact eyes and respiratory tracts in vulnerable individuals. Thus, occupants who are sensitive or have problematic health conditions could possibly react to even low indoor levels of formaldehyde in the classroom (OEHHA, 2000).

Unfortunately no specific guideline limit for TVOCs is recommended by any governmental or federal agency. The average concentration of TVOCs in classroom A1, A2, B1, B2, B3, C1, C2, D1,D2 were 368, 408, 293, 620, 380, 524, 268, 319 ppb respectively.

The highest indoor value for TVOCs was obtained in classroom B2. In classroom B2 at the time that an air freshener was sprayed in the classroom, the indoor concentration of the TVOCs quickly reached 1097 ppb. The main sources for high indoor value of TVOCs in selected classrooms were the use of air fresheners and detergents. In addition, exhaust fumes from vehicles polluted the outdoor air around the school. Consequently, the ventilation system (especially natural ventilation) brought in the outdoor contaminant to the indoor environment. Many of reported symptoms in classroom B2 could be correlated to the indoor concentration of TVOCs.

In classroom C2, the measured concentration values of TVOC were high during the morning. The classroom was cleaned by detergent before the start of school day (before 7:30 a.m.); thus, the indoor level of volatile organic compounds was at an elevated level during early hour of the school day (first session). Closeness of the school to the main road, high density traffic rate in the neighbourhood and nearby public parking could cause elevated level of pollutants in the school environment. Throughout the study in classroom C2, the door was opened numerous times, which affected the indoor level of pollutants. A deodorizer was sprayed inside the room several times from 11:30 to 11:53 a.m. As a result indoor concentration values of TVOCs were in ascending order. While all mechanical ventilation systems (3) were used and the door was closed, the indoor concentration values of TVOCs were in decreasing order. In addition the indoor level of all other contaminants decreased during that time. Thus, by proper use of mechanical ventilation systems during peak time (high traffic rate) and no natural ventilation (closed door), the indoor air will be improved.

It is recommended to not clean the room in the early morning before the start of class sessions. The air freshener products which contain high level of TVOCs should not be used for deodorizing the room (Cruz-Martínez, 2008; Shendell et al, 2004a).

5.1.6 Health Symptoms Associated with Indoor Pollutants

Children body types are different than adults; their body is not developed and they are not immune to many of the pollutants. They are more susceptible to indoor contaminants of the classroom compared to adults. Taking no action for preventing indoor air contamination may amplify the risk of acute or chronic illness for children. Indoor contaminants can reduce teacher’s concentration level and performance. In addition, a polluted indoor environment decreases students’ comfort, performance and learning ability (Ismail et al, 2010). According to a study conducted by EPA (2003), usually students suffering from short-term physiological symptoms have low capability to do particular school assignments which need focus or remembrance. Poor condition of the indoor air can cause ill health and lead to missing an entire lesson (absence).

Students who complained about physiological symptoms such as headache, sneezing, coughing, strained eyes, irritated or dry eye, fatigue, lack of concentration, pain or discomfort, nervousness, and irritated skin whilst they were in the classroom environments were proof of indoor air quality problems. In all the selected schools, the majority of symptoms were gone when the occupants are away from school. This may indicates the SBS problem.

The majority of the students did not complain, but this does not mean that the air quality was fine. Bener et al (1994) and Joseph et al (2009) declare that the number of asthmatic children and children who suffer from respiratory health problems are increasing in the UAE. Therefore the, indoor environment in buildings (residential, educational, etc) is probably not good enough for children. According to the study by Rumchev et al (2004) exposure to some VOCs such as benzene and toluene can highly raise the risk of developing asthma in children even if the specific VOCs are lower than current recommended limits. The Polluted indoor environment in houses and schools can cause serious health problems in children.

People should take sick or sensitive individuals into consideration when they are assessing IAQ. The knowledge gained from literature review guides the researcher to say that the indoor contaminant even at threshold limits can cause health problems for sensitive individuals. Indoor concentration level of contaminants should be as low as possible since contaminants accumulate in the body over time and can cause serious health problems. Thus, exposure to pollutants even at low concentration is a major health concern especially if children are exposed to pollutants on regular basis. Mechanical ventilation system of the classroom must be checked as frequent as possible in order to check proper operation. Filters of air conditioning systems should be changed/ cleaned regularly in order to improve the IAQ.

Most common physiological symptoms between all studied classrooms were dry or itchy skin and sneezing. Perhaps symptoms indicated the reaction of students' bodies to an indoor environment. It is apparent that students diagnosed with eczema were more at risk of skin rashes and skin problems. Probably there is strong association between high concentrations of TVOCs and eczema problems. Prohibiting the use of air fresheners, which contains high VOCs levels, in classrooms can reduce the risk of having problematic skin symptom**s**. In addition, minimizing the use of detergents that emits high level of VOCs may help to create healthier indoor air. Students who reported a doctor diagnosis of unfavourable health conditions (e.g. eczema, asthma, allergy to dust, etc) complained of at least one physiological symptom. The number of people who complained of problematic symptoms was higher in school B compared to other studied schools, since many students in classroom B1 had problematic health conditions such as allergy to dust and eczema. Thus, they complained of physiological symptoms. Those symptoms are more likely caused by exposure to high level of TVOCs in the environment of classrooms. Sensitive individuals (e.g. students with asthma problems) in classroom B1 and B2, which use high VOCs emitting products, complained about dry or itch skin and sneezing while they are in the classroom environment. According to a study by EPA (2003), high levels of VOCs in office environment can reduce the performance of the sensitive individuals; however, it cannot necessarily impact individuals who are not susceptible. Thus, performance of sensitive students who suffer from problematic health conditions will decrease and this will affect their academic achievement.

Peters et al (1997) states that elevated levels of particulate matters in the school is linked with an amplified rate of respiratory problems, and absences. According to Raabe (1999), exposure to particulate matter in the air can cause respiratory symptoms such as sneezing and coughing. As particles (large particles) were inhaled by students, they had a propensity to collect in upper respiratory tracts (nose and throat). Subsequently, the students' bodies tried to get rid of them by sneezing. Current research study found that in carpeted classroom, students who reported a doctor diagnosis of allergy or asthma complained mainly about sneezing.

According to the study by Simoni et al (2010) high risk of suffering from dry cough and wheezing in school indicates a high level of carbon dioxide concentration and PM (10). Irritation in upper respiratory part was widespread among students in schools with PM and CO_2 problems which eventually caused sickness and lead to a high absentee rate. Simoni et al findings may have some correlation with findings of current studies since few students (particularly sensitive individuals who were asthmatic or allergic to dust) experienced wheezing, coughing and sneezing.

The study by Kjaergaard and Wolkoff (2007) points out that RH lower than 30% is not good for the health and comfort of occupants. RH less than 30% can cause irritated eyes and upper respiratory problems. Only in school A, the average of indoor RH (26%) were below recommended limit; In classroom A1 16 % of students complained about dry eye or irritated eyes. This eye irritation was most likely caused by RH or VOC's.

Although the Health Authority in Abu Dhabi (HAAD) does have some standards about ventilation and air contaminants, the United Arab Emirates (UAE) does not have IAQ standards at the moment. Creating national standards for IAQ is required in order to improve the quality of indoor air across the UAE. This cross-sectional (short term) study of primary schools demonstrates that majority of selected classrooms have some indoor air quality problems. Understanding the health impact of particular indoor air contaminants cannot comprehensively determine the health condition of occupants and indoor air quality condition of the classrooms (Green Facts, 2008), but the recognition of the main indoor pollutants, their sources and appropriate solutions can protect building occupants from critical health problems and assess IAQ conditions.

5.2 Thermal Comfort

In order to determine the most favourable thermal conditions in an enclosed microclimate, the majority of the investigated research on thermal comfort conditions used ISO standard 7730 or ASHRAE standard 55. Various field experiment investigations in warm and humid regions demonstrated that proposed temperatures obtained from ISO standard 7730 or ASHRAE 55 standard may not be very practical since it may need further energy to attain a thermally comfortable indoor environment than what is designated from the outcome of the survey questionnaire (Hwang, and Cheng, 2007). According to Mors (2010), children's thermal sensations may not be similar to the thermal sensation model based on mentioned standards since associations between children's surface body temperatures, sweat production, metabolic rate and thermal comfort conditions may be different from adults. This study evaluates the comfort condition of occupants solely based on the result of the survey questionnaire; therefore, the actual level of comfort was considered for this study.

According to the survey questionnaire, the distribution of the votes varied for each classroom. It was not easy to achieve thermally comfortable conditions inside school buildings due to a variety of environmental factors (main environmental or physical factors: relative humidity, air speed, temperature) and human factors (main personal factors: clothing, and activity (metabolic rate)). It was observed that most of physical parameters were in an acceptable range in the majority of classrooms, but personal factors needed some modifications.

5.2.1 Environmental Parameters

In any place that non-natural ambiance are made for the building inhabitants, the endeavour is to create thermal setting that grants thermal comfort for all inhabitants. Therefore, the foremost plan of the air conditioning and heating system is to generate a thermally comfortable indoor environment for occupants (Çakir, 2006). In regions that HVAC systems in buildings are mainly mechanical due to specific climates (e.g. hot and humid regions in the Middle East), proper designing of the school building and designing and operation of HVAC systems can impact the thermal comfort in classrooms.

Creating an indoor thermal condition that can fully satisfy every occupant in the classroom is not really obtainable, since individuals have different thermal preferences. Teachers satisfaction votes revealed that generally the teachers felt comfortable with the thermal setting of their classrooms since they voted for either very satisfied, satisfied or neutral. Apart from collected information from classroom A1 and B1, the overall collected data demonstrated that the majority of students in the studied classrooms were mostly comfortable with the indoor thermal condition of their classroom.

Results of the thermal comfort questionnaire in the classroom A1 was very different compared to other studied classrooms. The outcome of the questionnaire indicates that many of occupants were dissatisfied since majority of occupants votes were distributed on the warm part of the scale. The Acceptability of humidity and air speed can point out a high clothing insulation level. The clothing insulation values and indoor temperature were probably the main parameters that negatively affected students thermal comfort condition. Classroom D2 had the lowest average indoor temperature among selected classrooms. Climatic conditions of classroom D2 was acceptable (42 %, 18°C, 3.8 m/s) for majority of the occupants in classroom D2. The Collected information from classroom D2 indicated that many of the students were satisfied with the thermal condition of the room, even though the average value of clothing insulation was low; this may indicate that many students preferred cold indoor environment (indoor temperature was 18°C). Students probably get used to low indoor temperature since they had been experiencing similar temperatures for pervious weeks.

A Study conducted by Humphreys (1977) indicates that the thermal sensation votes among young boys and girls could be very diverse, but the difference between the thermal satisfaction vote of the male and female subjects was not considerable. The current study found that overall rate of satisfaction vote between male (classroom C2) subjects was more than female subjects (classroom A1) while indoor temperature in both classrooms was similar (around 26 °C). In both classrooms, the average of indoor air speed, relative humidity, and clothing level were different. Perhaps a combination of those factors with the indoor temperature created a condition which was satisfactory for many students in classroom C2 and unsatisfactory for A1.

According to Humphreys (1973), the indoor temperature of the classroom should not go beyond 26 °C since it adversely affects the thermal comfort conditions of children. From the overall results, we can state that male students in classroom C2 were able to bear a 26.5 °C temperature and felt slightly comfortable, while students of classroom A1 were not pleased about the thermal environment of their classroom which had very similar temperature (26 °C). A thermal comfort condition is not only related to temperature, but it is result of a combination of personal factors and environmental factors (temperature, air movement and humidity). Thermal sensation and comfort range in both classrooms may indicate that male students are capable of handling higher indoor temperature compared to female students. Various assumptions can be made for higher tolerance of boys compared to girls. According to the teacher of classroom C2, students' of classroom C2 had been experiencing hot indoor temperature for few times in the previous week. Consequently, students could tolerate higher indoor temperatures since they have adapted themselves with the thermal setting of the room.

EPA (2009a) has recommended humidity and temperature ranges for classrooms which are adopted from ASHRAE Standard 55-1992. According to EPA, during summer time majority of the classroom's occupants (80%) will feel comfortable at approximate temperature of 23°C to 27°C and humidity 30% to 50 % while they complete sedentary activities and wear typical summer clothing. Recommended values of temperature should be modified for the hot and humid climate of Dubai and for the young students since the findings of this research has some controversy with the mentioned temperature range. However, the rate of complaints indicates a need for modification (e.g. make the classroom cooler or hotter). The dissatisfaction votes are not very high at temperature of 26 °C, but overall collected votes for temperature between 18 to 23.5°C were more optimistic. According to this study finding, it can be concluded that temperatures between 18 to 23.5 °C seem to be more acceptable for young students while relative humidity level is between 30 to 45%. In all studied schools averages of RH during surveying time were between 30 to 45% and the majority of students did not have any complaints. In general the majority (60% to 100%) of students did not complain about indoor air speed of their classroom. Most preferred thermal condition occurred when indoor air speed was 5.8 m/s, indoor temperature was 23°C and relative humidity was 41%.

In general, people who voted for cool, slightly cool, neutral and slightly warm appeared to be content with the thermal condition of their classroom. Most occupants who felt cold voted for either neutral or satisfied in the thermal satisfaction scale. Thus, students whose vote were not within the central three category of thermal sensation scale (slightly cool, neutral and slightly warm) could also feel comfortable.

The National Union of Teacher (NUT, 2010) declared that the warm temperature of indoor air in classrooms can cause exhaustion and loss of concentration. Young students probably suffer in hot indoor temperature since they do not know many ways of behavioural adaptations with unfavourable air temperature. Therefore, schools should put more consideration into thermal conditions of their classrooms in order to create a healthy and comfortable indoor condition.

5.2.2 Personal factors

In many of the thermal comfort researches, garments insulation level is not precisely calculated since they use rough garments insulation values specified in various guidelines (e.g. ISO 9920 or ASHRAE). Clothing material or styles (e.g. loose or tight fit clothing) are not accurately considered in guidelines. The suggested insulation values are roughly calculated.

Inaccurate estimations of the definite insulation value cannot truly reveal the dissimilarity between thermal preferences of occupants. Thus, this study only considers the layer of clothing since type of clothing and material of clothing that occupants wore under their uniform cannot be exactly calculated. In addition, students can easily count the layer of garments that they wore, but they probably can not specify the type, thickness and material of their clothing.

Findings of this study have some conformity with the study of Gado and Mohamed (2009) who declares that adding or removing a layer of garment in a classroom environment can help children to adapt themselves with the thermal setting of the classroom and feel comfortable. They found a high level of discomfort in schools with a special dress code. Students had limited options to adjust their level of clothing due to a special dress code (uniform) of their school (school uniform). According to school rules and policy they were not able to remove an extra layer of clothing that they wore under their uniforms while they felt hot. Garments insulation levels can influence exchange of individual’s body heat with the classroom environment since it creates a barrier that affects heat transfer (thermal radiation, and heat convection) between their body and their surroundings. Unfavourable levels of clothing can affect thermal comfort conditions of occupants.

Study by Chun and Kwok (2003) compared schools with a special dress code (specific uniform) and schools with no dress code. They declared that children could not have a control over thermal setting of their classroom and they could not control fans or air-conditioning systems in order to generate preferred indoor thermal setting, but they could easily use adaptive behaviour to achieve thermal comfort. Their findings demonstrated that uncomfortable thermal conditions were commonly claimed by students in schools with special uniform. Students' body could not easily lose heat in order to achieve thermal comfort since adaptive behaviour such as adding or removing a layer of clothing in their schools was forbidden. On the contrary, students were more thermally satisfied in schools with open dress codes. It was observed that students used sweaters and sweatshirts in cold classrooms and they removed it while they were in hot areas in school. They could adjust the layer of their clothing according to the thermal setting of the room. Hence, they had more thermal adaptation options compared to schools with a special uniform policy. Findings from mentioned research could be helpful for improving thermal comfort levels of students in studied classroom.

In this study we observed that male students were more capable of quickly adjusting layers (some of them brought jackets) of their clothing in relation to the indoor temperature. Female students had more problems with thermal setting of their classroom since usually they wore excessive layers of clothing under their uniform. The girls could not change their excessive level of clothing probably because of uneasiness of removing their uniform and for some personal and cultural factors. Having personal capability to control the indoor thermal setting is not really possible in majority of the elementary schools, since students had various preferences to achieve comfort. The easiest way to control unfavourable heat or cold could be adjusting their layers of clothing. Considering the school dress code, maximum garments layers could be suggested as follows: maximum two layers of clothing (during spring and summer) in the top half of the body and 2 layers of clothing in lower half (without considering shoes and socks). Two layers of clothing in upper and lower half of the body seem more appropriate according to student's votes, but the school should give an option such as wearing jacket, sweaters or summer coat on top of the uniform. By adding or removing extra layer (jacket) students can adjust the insulation level of their clothing and feel more satisfied.

Humphreys (1973) pointed that children wearing jumpers as part of their school uniform need lower indoor temperature compared to students who wear a shirt or blouse. Thus, girl students who wore jumper and blouse (dressing code of the school A) required lower indoor temperature in order to feel comfortable compared to boy students who wore short sleeved blouse and trouser (dressing code of the school C).

High temperature toleration of males could be due to differences in the type or layer of clothing or it may be due to student's different social-economic backgrounds. It can even be as a result of superior adjustment of males' body to harsher climatic condition compared to females. Generally young Emirati boys spend more time playing in outdoor spaces (hot outdoor temperature) compared to girls. Since boys spent more time playing in hot outdoor climates, their bodies can tolerate higher temperatures. There is a need for further investigation to precisely determine the reason for higher tolerance of male subjects to higher temperatures in Dubai compared to female subjects.

Chapter 6: Conclusion

6.1 Conclusion

Primary schools were selected for this study due to the elevated health risk linked to children of this age group. In addition, considerable numbers of young students are currently studying in Dubai. Health and comfort of young students can easily get affected by polluted indoor air because their immune system and bodily organs were still developing. Thus, they may be highly vulnerable to indoor pollutants.

There are not many studies about indoor air quality in educational establishments. Thus, findings from current study can be very useful for other researchers. The current research study revealed that the majority of selected classrooms have some indoor air quality problems and this may have negative effect on the performance of the children. It is important to improve this condition as studies on improvement of indoor air quality and thermal comfort in schools and office building demonstrate that occupants' health, performance, educational achievement (test scores) and attendance can be considerably enhanced by improving indoor air quality and thermal condition (EPA, 2003; Heath and Mendell, 2002).

A cross-sectional (short term) study was conducted in four primary schools (A, B, C, and D) in different locations in Dubai in order to evaluate indoor air quality and thermal comfort conditions of their classrooms. Schools A, B and D were built more than 20 years ago and school C around 7 years old. They are all courtyard buildings and two storeys they had almost comparable architectural style. In addition, they were all made of very similar construction materials. Hence, apart from their various locations, age or even size; all buildings were almost in equal condition.

At first, a walkthrough investigation was conducted for the selected schools, in order to analyse and evaluate parameters that could affect indoor air quality of the classrooms. Secondly, an indoor monitoring of physical parameters and chemical pollutants (CO2, CO, O3, TVOCs, and TPM) was conducted for 2 classrooms in each of the selected school. Thirdly, a survey questionnaire was conducted for the selected classrooms (A1, A2, B1, B2, C1, C2, D1, and D2). The total number of occupants (students and teacher) who responded to the survey questionnaire was 155 (147 students and 8 teachers).

As an overall conclusion, the main findings were as follows: firstly, levels of CO2, TVOCs and TPM in some of studied schools were high enough to cause a health or comfort problems. Ventilation systems in majority of schools were not adequate to dilute indoor air contaminants due to many contributing factors. Polluted indoor air was caused either by outdoor sources or indoor sources and sometimes both. Polluted outdoor air especially during rush hour was found to easily influence the indoor air whenever the classroom door was open. Classrooms which were cleaned prior to start of first class session in morning with detergent and classroom which are deodorized by air freshener spray had high indoor level of TVOCs. Students' activity on carpet was found to cause re-suspension of dust and particle from carpets fibres. Hence, carpeted classroom had higher indoor level of TPM compared to non carpeted classroom. Outdoor air supplied by mechanical systems in schools with frequent (monthly) maintenance/cleaning was less contaminated than schools with lower maintenance/cleaning level. This might be due to filter problem which is may serve as source of pollutants (Clausen, 2004). Secondly, allergic and asthmatic children had higher rate of complains from health symptoms compared to others. Students who suffer from problematic health conditions (e.g. asthma, allergies) are at higher risk if they get exposed to indoor air contaminants such as TVOCs and TPM. In order to protect the wellbeing of occupants, it is very important to limit their exposure to indoor air contaminants in school environment. Thirdly, students who wore more than 2 layers of clothing (upper and lower halves of their body) generally did not feel comfortable. Perhaps, layers or type of clothing in schools need some modification. Fourthly, indoor air temperature above 26 °C was found to cause discomfort for children since overall satisfaction rate for classroom with 26 °C temperature was not as optimistic as lower indoor temperatures. Finally, a type of guide (toolkit) needed for schools indicating a step by step guide that needs to be taken to help the students/staff and teachers.

From the results analysis and evaluation, it would be safe to say the four schools investigated and all schools across the Emirates need to be assessed on a regular basis, in order to improve indoor air quality of classrooms. The study also firmly introduces key issues that need to be addressed. Ignorance about indoor environmental quality was found to be among schools studies. This is likely to be a true picture of most UAE schools. The ignorance will only disappear once more studies are administered and results published and shared in a positive manner and toolkits are produced and helped delivered across the schools.

Unfortunately studies on thermal comfort and indoor air quality in schools particularly primary schools are very limited in the UAE. This seemed to be the only study on indoor air quality and thermal comfort condition within schools in Dubai and properly in the whole UAE. Whilst the sample size was relatively small (four schools), significant new information was gained which offer a better understanding of occupants health and comforts within the indoor environment in schools. Further work should be carried out by the KHDA and the Dubai Government on more schools across the Dubai, focusing especially on the major issues highlighted by this study and extending it to other issues, such as establishing the impact of the indoor environment on student's performance.

The welfare of the students, staff and teachers needs to be paramount. The idea of effective IAQ management needs to follow a certain criteria. Based on this study, the author would suggest the following. Firstly, sharing the goals with all stakeholders and educating staff about the different aspects of IAQ in order to progress required policies and improve the indoor environment of schools. This may encourage them to create a healthy indoor environment. Secondly, build an effective team. From personal experience from this study, a larger more resourceful team would help achieve goals quicker and therefore evaluation would be achieved faster and probably more comprehensive. Thirdly, use the latest technology to assess and determine factors impacting IAQ. In order to comprehensively assess indoor air quality all types of indoor air contaminants (chemical and biological) in schools must be investigated and their affect on students' health and comfort must be studied. Fourthly, determine accurate baselines. Using highly regarded institutes including WHO, EPA, ASHRAE, etc. Dubai government may adopt/create their own baselines (different climate/ temperature and humidity). Criteria can also be implemented in the planning, building and construction of new schools in the Emirates. This baseline could also be used across similar geographical areas especially across the Middle East.

6.2 Recommendations

This study recommends the following based on EPA (2009a) recommendations and knowledge gained from this study. Firstly, all schools should develop a preventative maintenance plan with the help of the maintenance contractors. Quality HVAC inspections of school environments to be carried every 3 months (monthly would be better) across all schools to check the operation of HVAC system. For example, inspect and change/ clean filters should take place on regular basis in order to prevent supply of polluted outdoor air as much as possible. Dust and particle usually gathered on the filter and affect the performance of air-conditioner systems. By cleaning or changing (if required) filters, the quality of indoor air can be improved. Where possible, use high-efficiency filters to enhance the operation of mechanical ventilation system. Secondly, establish an anti-idling school bus policy and keep the buses and traffic away from the school environment. Closeness of school bus parking plot to classrooms is dangerous for occupant's health. Unnecessarily idling of vehicles can pollute out air and consequently indoor environment of classrooms. Thirdly, train/inform cleaning/maintenance staffs on importance of all parameters and preventions. Ask maintenance contractors to use only low-toxicity and low-emitting paint (most schools get re-painted during the summer vacation) and preferably non-toxic paint. Air quality test can also be planned and implemented whenever renovation takes place in schools. Inform cleaning maintenance staff to use least poisonous cleaning product with low level of VOCs emission. Fourthly, try not to use carpet in crowded areas in which occupants would wear shoes. If carpet is used in classroom, proper and regular cleaning and vacuuming must take place. In addition, occupants must remove their shoes while they sit on the carpet. Fifthly, while classroom is occupied by students try to minimize opening the door and window during peak/ rush hour (high traffic rate) due to polluted outdoor air. Finally, medical nurses need to be present in school documenting health and welfare of students and staff. All records regarding illnesses such as asthma, eczema, fatigue, headaches, and migraines need to be kept. Collected data can help school management to be more conscious about indoor air.

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Appendix 1: Thermal Comfort and Indoor Air Quality Questionnaire

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Name:

Date: / /2011 Time: School name: classroom:

Male/ Female

1. **How old are you?**
2. **What is your weight and height?**
3. **How do you feel with the current temperature of the classroom?**

Very Cold	Cool	Slightly cool	Neutral	Slightly warm	Warm	Very Hot

4. **If you can change the classroom temperature which of the following is your preference?**

a. No change, it is already fine (Acceptable)
b. Make it warmer
c. Make it cooler

5. **How do you perceive humidity level of the classroom?**

a. Acceptable
b. Too humid
c. Too Dry

6. **How do you perceive air speed (air movement) level of the classroom?**

a. Acceptable
b. Too much air speed
c. Too little air speed

7. **How many layers of clothing are you wearing today on top part of your body?**

a. One
b. Two
c. Three
d. Four or more than four

8. How many layers of clothing are you wearing today on the down part of your body?

a. One
b. Two
c. Three
d. Four or more than four

9. What kind of shoes are you wearing today?

a. Sandals
b. Closed toed shoes

10. What is your most ideal activity to feel thermally comfortable?

a. Adding or removing the layer of clothing
b. Opening the windows
c. Moving away or closer to the cooling or heating source (moving away from the air conditioning direct pathway, moving away from the sun penetration in to the indoor environment)
d. Closing the curtains
e. Switching on or off the fan
f. Switching on or off the air conditioning system

11. At the moment do you feel comfortable with the classroom environment (temperature, humidity, air speed (wind)?

Very satisfied	satisfied	fairly acceptable	Neutral	Slightly dissatisfied	unsatisfied	Very dissatisfied

12. What type of corrective lens do you use while you are in the school?

a. I am not using any corrective lens (none)
b. Glasses
c. Contact lens
d. Bifocals

13. Do you consider yourself particularly sensitive to presence of chemicals in the air of your classrooms?
Yes___ NO___

14. Have you ever been told by a doctor or any specialist that you have any of the problems below?

Problem	Yes	No

migraine		
asthma		
eczema		
Hay fever (Allergic rhinitis)		
Allergy to dust		
Allergy to mould		

15. Please answer the question in the box by filling up

(a) During the last 4 weeks how often have you experience any of the below symptoms, while you are in the school (classroom)?

Symptoms	Not in last 4 weeks	1-3 days in the last week	1-3 days per week in last 4 weeks	Every or almost every school day
dry eye, itching eye, or irritated eyes				
Tired or strained eye				
Blurred vision				
Wheezing				
Sore or dry throat				
Unusual downiness, fatigue, or tiredness				
Headache				
Nausea or upset stomach				

Stuffy or runny nose or sinus congestion				
Sneezing				
Coughing				
Shortness of the breath				
Dizziness or light-headedness				
Dry or itchy skin				
Difficulty in remembering thing or difficulty in concentrating				
Nervousness, tension or irritability				
Pain or discomfort (stiffness) in back, chest, neck, wrest, other				

16. How often you use the following at school (Only teacher)?

	Several time a day	**About once a day**	**3-4 time a week**	**Less than 3 time/ week**	**Never**
Laser printer					
Photocopier					
Facsimile machine(Fax)					

Self copying carbon-less copy paper					
Cleanser, glue, correction fluid, spray, or other odorous chemical					

17. During the past three months have the following changes taken place within 4.5 meters of your current classroom (Only teacher)?

	Yes	**No**
New carpeting		
Walls painted		
New Furniture		
New partitions		
New wall covering		
Water damage		

18. What is your tobacco smoking status (Only teacher)?

a. Never Smoked
b. Former smoker
c. Current smoker

*Question 12-18 are adopted from EPA Base Indoor Environmental Quality Survey

* Question 4-11 are adopted from Thermal Comfort Survey from ASHRAE 55-2004

Appendix 2: Thermal Comfort and Indoor Air Quality Questionnaire (Arabic)

التاريخ : / / 2011 **الوقت :----------** اسم المدرسة :----------- **الصف :-------------**

ذكر / أنثى

---

1. كم عمرك؟
2. ما هو وزنك و طولك ؟
3. كيف تشعرحاليا بدرجة الحرارة في الصف؟

باردة جدا	باردة	باردة قليلا	معتدلة	دافئة	دافئة قليلا	حارة

4. إذا يمكنك تغيير درجة حرارة الغرفة فما الذي تفضله مما يلي ؟
أ. لا داعي للتغيير، فإنها مناسبة
ب. جعلها أكثر دفئا
ج. جعلها أكثر برودة

5. كيف ترى مستوى الرطوبة في الصف؟
أ. مقبولة
ب. رطب جدا
ج. جاف جدا

6. كيف تتصور سرعة الهواء (الهواء الحركة) في مستوى الصف؟
أ. مقبولة
ب. سرعة الهواء كبير جدا
ج. سرعة الهواء قليلة جدا

7. ما هو عدد طبقات الملابس التي ترتديها في الجزء الاعلي من جسمك؟
أ. واحد
ب. اثنين
ج. ثلاثة
د. أربعة أو أكثر من أربعة

8. ما هو عدد طبقات الملابس التي ترتديها في الجزء الأسفل من جسمك؟
أ. واحد
ب. اثنين
ج. ثلاثة
د. أربعة أو أكثر من أربعة

9. ما هو نوع الحذاء الذي ترتديه اليوم؟
أ. صندل
ب. الأصابع حذاء مغلق

10. ما هو النشاط الافضل لتشعر بالراحة حراريا؟
أ. إضافة أو إزالة طبقة من الملابس
ب. فتح النوافذ
ج. الابتعاد أو أقتراب من مصدر التبريد أو التدفئة (الابتعاد عن مسار تكييف الهواء مباشرة، والابتعاد عن أشعة الشمس في البيئة الداخلية)
د. إغلاق الستائر
ه. تشغيل أو إيقاف المروحة
ف. . تشغيل أو إيقاف نظام تكييف

11. في هذه اللحظة هل تشعر بالراحة د خل البيئة الصفية (من حيث درجة الحرارة والرطوبة وسرعة الهواء (الرياح))؟

راض جدا	راض	راض إلى حد ما	مقبول	مستاء قليلا	مستاء جدا	رافض

12. ما هو نوع العدسات الطبيه التى تستخدمها أثناء تواجدك في المدرسة؟
أ. أنا لا تستخدم أي او عدسات (لا يوجد)
ب. النظارات
ج. عدسة لاصقة
د. النظارة ثنائيه الابعاء

13. هل تعانى من حساسية من نوع معين من المواد الكيميائية في الهواء الغزفة الدراسية؟
☐ نعم ☐ لا

14 .هل سبق أن قال لك طبيب أن لديك أي من المشاكل المذكورة أدناه؟

المشكلة	نعم	لا
صداع نصفي		
الربو		
الأكزيما		
حمى القش (التهاب الأنف التحسسي)		

حساسية من الغبار		
حساسية من العفن		

15. الرجاء الإجابة على السؤال عن طريق تعبئة الجدول الأتي:

(أ) خلال ال 4 أسابيع الماضيةهل واجهت أي من الأعراض المذكور ادناه ،اثناء تواجدك في المدرسة (الصف)؟				
الأعراض	ليس في أي من الأسابيع ال 4 الاخيرة	1-3 أيام في الأسبوع الأخير	1-3 أيام في كل الأسبوع من ألأسابيع الأربعة الاخيرة	كل أو تقريبا كل يوم
جفاف العين، حكة العين				
تعب أو توتر العين				
عدم وضوح الرؤية				
الصفير عند التنفس				
التهاب في الحنجرة				
التعب ، أو الإرهاق				
صداع				

(أ) خلال ال 4 أسابيع الماضيةهل واجهت أي من الأعراض المذكور ادناه ،اثناء تواجدك في المدرسة (الصف)؟

الأعراض	ليس في أي من الأسابيع ال 4 الاخيرة	1-3 أيام في الأسبوع الأخير	1-3 أيام في كل الأسبوع من ألأسابيع الأربعة الاخيرة	كل أو تقريبا كل يوم
الغثيان أو اضطرابات المعدة				
انسداد أو سيلان الأنف أو احتقان الجيوب الأنفية				
العطس				
السعال				
ضيق في التنفس				
الدوخة أو الدوار				
حكة في الجلد الجاف				
صعوبة في تذكر شيء أو صعوبة في التركيز				
العصبية والتوتر أو التهيج				
الألم أو عدم الراحة (تصلب)في الظهر والصدر والرقبة ، وانتزاع وغيرها				

16. كم عدد المرات التي استخدمت فيها ما يلي باالمدرسة (المعلم فقط)؟

	أقل من ثلاث مرات في اليوم	3-4 مرات في اليوم	مرة واحدة كل يوم	عدة مرات في اليوم	أبدا
طابعة الليزر					
الة تصوير					
الفاكس					
النسخ الذاتي (النسخة الكربونية للورقة)					
المطهر ، الصمغ ، وسائل التصحيح،الرش، أو غيرها من المواد الكيميائية المعطرة					

17. خلال الأشهر الثلاثة الماضية ، هل قمت بالتغييرات التالية التغييرات في قاعة الصف (معلم فقط)؟

	نعم	لا
سجادات جديدة		
تغيير صبغ الجدران		
تغيير الأثاث		

		فواصل / حواجز
		تغيير أوراق الجدران

18. ما هو وضعك في التدخين (معلمة فقط)؟

أ. غيرمدخن
ب. مدخن (سابقا)
ج. مدخن(حاليا)