Sudan University of science and Technology

College of Engineering

Mechanical Engineering

Power Department

EXPERIMENTAL ASSESSMENT OF INDOOR ENVIRONMRNTAL QUALITY IN STUDIES HALL

تقييم عملي لجودة البيئة الداخلية في القاعات الدراسية

A graduation project submitted in partial fulfillment of the requirements for the degree of Bachelor in mechanical engineering

Prepared by:

1- Al-Hassan Fadl Alatti Al-Hassan Ahmed

2- El-Moez Elgenaid Elamin Mohamed

3- Mohammed Omer Abdalwahab Mohammed

Supervised by :

Dr.A.A.A.Abuelnuor

OCTOBER 2017

الايه

بسم الله الرحمن الرحيم

قال تعالى :

(وَعِبَادُ الرَّحْمَنِ الَّذِينَ يَمْشُونَ عَلَى الأَرْضِ هَوْنًا وَإِذَا خَاطَبَهُمُ الْجَاهِلُونَ قَالُوا سَلامًا

* وَالَّذِينَ يَبِيتُونَ لِرَبِّهِمْ سُجَّدًا وَقِيَامًا * وَالَّذِينَ يَقُولُونَ رَبَّنَا اصْرِفْ عَنَّا عَذَابَ جَهَنَّمَ إِنَّ عَذَابَهَا كَانَ غَرَامًا * إِنَّهَا سَاءَتْ مُسْتَقَرًّا وَمُقَامًا * وَالَّذِينَ إِذَا أَنفَقُوا لَمْ يُسْرِفُوا وَلَمْ يَقْتُرُوا وَكَانَ بَيْنَ ذَلِكَ قَوَامًا * وَالَّذِينَ لا يَدْعُونَ مَعَ اللَّهِ إِلَهًا آخَرَ وَلا يَقْتُلُونَ النَّفْسَ الَّتِي حَرَّمَ اللَّهُ إِلاَّ بِالْحَقِّ وَلا يَزْنُونَ وَمَن يَفْعَلْ ذَلِكَ يَلْقَ أَثَامًا * يُضَاعَفْ لَهُ الْعَذَابُ يَوْمَ الْقِيَامَةِ وَيَخْلُدْ فِيهِ مُهَانًا * إِلاَّ مَن تَابَ وَآمَنَ وَعَمِلَ عَمَلا صَالِحًا فَأُولَئِكَ يُبَدِّلُ اللَّهُ سَيِّئَاتِهِمْ حَسَنَاتٍ وَكَانَ اللَّهُ غَفُورًا رَّحِيمًا * وَمَن تَابَ وَعَمِلَ صَالِحًا فَإِنَّهُ يَتُوبُ إِلَى اللَّهِ مَتَابًا * وَالَّذِينَ لا يَشْهَدُونَ الزُّورَ وَإِذَا مَرُّوا بِاللَّغْوِ مَرُّوا كِرَامًا * وَالَّذِينَ إِذَا ذُكِّرُوا بِآيَاتِ رَبِّهِمْ لَمْ يَخِرُّوا عَلَيْهَا صُمًّا وَعُمْيَانًا * وَالَّذِينَ يَقُولُونَ رَبَّنَا هَبْ لَنَا مِنْ أَزْوَاجِنَا وَذُرِّيَّاتِنَا قُرَّةَ أَعْيُنٍ وَاجْعَلْنَا لِلْمُتَّقِينَ إِمَامًا * أُوْلَئِكَ يُجْزَوْنَ الْغُرْفَةَ بِمَا صَبَرُوا وَيُلَقَّوْنَ فِيهَا تَحِيَّةً وَسَلامًا * خَالِدِينَ فِيهَا حَسُنَتْ مُسْتَقَرًّا وَمُقَامًا)

DEDICATION

Dedicated to the beloved Ummah

To the most precious persons in our

life, our fathers, mothers and

families.

ACKNOWLEDGEMENT

Thanks to ALLAH, the Most Gracious, the Most Merciful, the Most Bountiful who gave us the courage and patience to accomplish this research work. Without his help and mercy, this would not have come into reality.

We would like to deeply express our gratitude for the help and support from our supervisor Dr. A.A.A.Abuelnuor on his fascinating guidance, encouragement, and valuable comments throughout the research work. We fortunate to be one of his graduate students. His experience and creativity gave us great profit for carving our future career.

Finally, our greatest thanks from our heart to our families for giving the unlimited supports and helping us financially and morally to finish our study.

ABSTRACT

Indoor environment of buildings has attracted increasing attention. Therefore ,advanced building technologies are essential not only for reducing energy consumption , but also for creating a comfortable and healthy indoor environment for buildings by measuring the rate of temperature , humidity and air velocity . Thermal comfort in study halls has lately been receiving more research attention because healthy environment has a big impact on students health and concentration and this experimental has been done in schools and universities in khartoum state . .This research shows the results of experimental study about indoor thermal comfort , based on investigation in Khartoum secondary schools . Different devices were used to take the measures . The animometer was used to measure the velocity of air and digital device was used to measure the rate of temperature and humidity in different locations inside the class depends on the location of teachers and students in class . Also the outdoor air temperature and humidity were measured to compare between inside and outside environment , temperature in public school between 35.8-36.2°C and the private school have ranged between 28.2-29.3°C the main goal of this study is to assessment indoor air quality inside class rooms . After analyzing these results we found that the majority of school environment is not suitable for students and study.

المستخلص

جذبت البيئة الداخلية للمباني اهتماما متزايدا ولذلك فان تقنيات البناء المتقدمة ضرورية ليس فقط للحد من استهلاك الطاقة ولكن ايضا لخلق بيئة داخلية مريحة وصحية للمباني عن طريق قياس معدل درجة الحرارة والرطوبة وسرعة الهواء . الراحة الحرارية في القاعات الدراسية تلقت في الاونة الاخيرة المزيد من الاهتمام والبحوث لان البيئة الصحية لها تاثير كبير على صحة الطلاب وتركيزهم وقد تمت هذه التجارب في المدارس والجامعات في ولاية الخرطوم , وتظهر نتائج هذه الدراسه التجريبية حول الراحة الحرارية الداخلية استنادا الى التحقيق في المدارس والجامعات في ولاية الخرطوم , واستخدمت اجهزة مختلفة لاخذ القراءات حيث تم استخدام جهاز الانيموميتر الرقمي لقياس سرعة الهواء وايضا جهاز ديجيتال رقمي لقياس معدل درجة الحرارة والرطوبة في مواقع مختلفة داخل القاعات الدراسية اعتمادا على مواقع تواجد الطلاب والمعلمين , كما تم قياس درجة الحرارة والرطوبة الخارجية للمقارنة بين البيئة الداخلية والخارجية , حيث تراوحت درجات الحرارة في المدرسة الحكومية بين 35.8 - 36.4 وفي المدارس الخاصة بين 28.2 - 29.3 , حيث ان الهدف الرئيسي هو تقييم البيئة الداخلية داخل القاعات الدراسية . بعد تحليل هذه النتائج وجد ان البيئة الداخلية في اغلبية المدارس غير مناسبة .

LIST OF CONTENTS

Content	Page
الايه	I
DEDICATION	ii
ACKNOWLEDGEMENT	iii
ABSTRACT	Iv
المستخلص	V
LIST OF CONTENTS	Vi
LIST OF FIGURES	X
LIST OF SYMBOLS	Xiii
TABLE OF ABBREVIATIONS	Xiv
CHAPTER ONE **INTRODUCTION**	
1.1 Background	2
1.2 Problem Statement	3
1.3 Objectives	4

1.4 Significance Of Study	4
CHAPTER TWO **LITERATURE REVIEW**	
2.1 Introduction	6
2.2 Indoor Environmental Quality (IEQ)	6
2.2.1 Environment in Residential buildings	7
2.2.2 Environment in Industries	8
2.2.3 Agricultural workers	8
2.2.4 Construction workers	9
2.2.5 Manufacturing workers	10
2.2.6 Environment In School	11
2.3 Impacts of Workplace Heat Exposure on Selected Susceptible Occupations	12
2.4 Methods of Air conditioning	13
2.4.1 Evaporative cooling	14
2.4.1.1 Types of evaporative cooling	15
2-4-1-2 Performance	17
2-4-1-3 Benefits of Evaporative Cooling	17
2.4.2 Window air conditioner	18
2.5 Current studies	18
CHAPTER THREE **METHODOLOGY**	

3.1 Introduction	24
3.2 Location	24
3.3 Experimental Steps	24
3.4 Experimental Devices	27
3.4.1 Animometer	28
3.4.2 Hygro-Thermometer	28
3.5 Experimental Procedures	29
CHAPTER FOUR **RESULTS AND DISCUSSION**	
4.1 Introduction	31
4.2 Results Analysis	31
4-2-1 Class in Al-Mawahb Primary School	31
4-2-2 Class in Al-Mawahb Secondary School	33
4-2-3 Class in Khalid Ibn Alwaleed primary school	35
4-2-4 Hall (3) in Sudan University of science and technology	36
CHAPTER FIVE **CONCLUSION AND RECOMMENDATIONS**	
5.1 Conclusion	38
5.2 Recommendations	38
REFERENCES	**40**

LIST OF FIGURES

Figure	Title	Page
1.1	U.S. building energy use in 2014	3
2.1	Functions of air conditioning	14
2.2	Direct Evaporative Air-Conditioning	15
2.3	Indirect Evaporative Air-Conditioning	16
3.1	Class in Khalid Ibn Alwaleed primary school	25
3.2	Class in Khalid Ibn Alwaleed primary school	25
3.3	Class in Al.Mawahb Primary School	26
3.4	Class in Al.Mawahb Primary School	26
3.5	Hall (3) in Sudan university of science and technology	27
3.6	The digital Animometer	28
3.7	The digital hygrometer	29
4.1	Class in Al.Mawahb primary School A.C is on	31
4.2	Class in Al.Mawahb Primary School A.C is off	32
4.3	Class in Al.Mawahb Secondary School A.C is on	33
4.4	Class in Al.Mawahb Secondary School A.C is off	34
4.5	Class in Khalid Ibn Alwaleed primary school	35
4.6	Hall (3) in Sudan University Hall (3) A.C is on	36

TABLE OF ABBREVIATIONS

OECD	Organization For Co-operation And Development
HSE	Health Safety and Environment
IEQ	Indoor environmental quality
HVAC	Heating ventilation and air condition
IAQ	Indoor air quality
AC	Air Condition
U.S	United State
ASHRAE	American Society Of Heating, Refrigerating and Air-Conditioning Engineers
TC	Thermal Comfort
VC	Visual Comfort
EAC	Evaporative Air-Conditioning
DDC	Direct digital control

LIST OF SYMBOLS

ϵ	direct evaporative cooling saturation efficiency (%)
$T_{e,db}$	entering air dry-bulb temperature (°C)
$T_{l,db}$	leaving air dry-bulb temperature (°C)
$T_{e,wb}$	entering air wet-bulb temperature (°C)

CHAPTER ONE

CHAPTER ONE

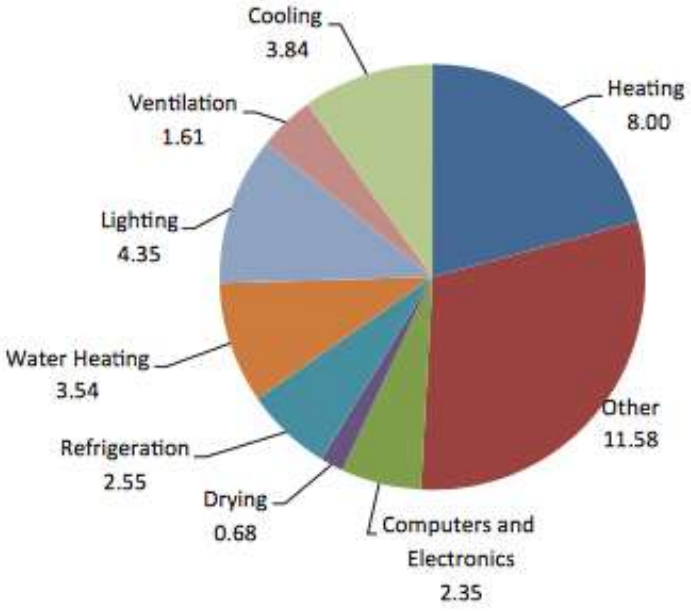
INTRODUCTION

1.1 Background

The building sector has a great impact on energy and material use, as well as on human health. The building sector accounts for around 25-40% of final energy consumption in OECD countries. An analysis of energy use in buildings indicates that space heating accounts for the largest proportion of energy consumption in both residential and commercial buildings[1].

Building materials play an important role in the construction of buildings with negative energy. The walls must be made of insulating materials that keep the heat in winter and prevent the high heat from entering the building, and finding more isolating glass windows is a main goal for designers of this type of building. The heat absorbent floors are also of basic design [2] .

More than 76% of all U.S. electricity use and more than 40% [1,3] , of all U.S Home heating devices in winter and cooling in summer are the most needed devices for energy and this makes them a reason to increase the cost and It is irreplaceable devices



figure(1.1) : U.S. building energy use in 2014 [3]

figure(1.1) shows U.S. building energy use in 2014 Space conditioning, water heating, and lighting represent well over half of the total, including energy used in outdoor lighting and cooling most data centers[3].

1.2 Problem Statement

Energy is one of the most important requirements life and the buildings sector is responsible for almost of energy consumption in worldwide . There are several ways to reduce electricity consumption , in this research the internal environment was studied to reach the optimal use of this energy .

1.4 Objectives

The objectives of this study are :

1- Experimental Study to the effect of the internal environment on the students in terms of health and concentration during the school day.

2- To evaluate the measures which taken from this experimental study.

1.3 Significance of Study

Many people spend most of their time indoors, and the quality of indoor air has a significant impact on their health and comfort Inadequate ventilation can make a room stuffy and uncomfortable .Throughout the developed world the energy required for constructing, operating and maintaining our buildings represents a major proportion of the prime energy consumed and of greenhouse gases emitted to the atmosphere. Reduction in demand is therefore key to ensuring sustainability of energy supply, making existing buildings more efficient and constructing new buildings with optimum energy demands. It is also necessary to take a whole life cycle approach to the evaluation of energy consumption considering the embodied energy of the building materials and the demolition and recycling of the materials at the end of the useful life of the building.

CHAPTER TWO

CHA TWO

LITERATURE REVIEW

2.1 Introduction

Health, Safety and Environment (HSE) is an umbrella term for the laws, rules, guidance and processes designed to help protect employees, the public and the environment from harm. In the workplace, the responsibilities for designing and implementing appropriate procedures is often assigned to a specific department, often called the (HSE) department which is responsible for environmental protection[2], occupational health and safety at work. HSE management has two general objectives: prevention of incidents or accidents that might result from abnormal operating conditions and reduction of adverse effects that result from normal operating conditions[1].

(ASHRAE) The American Society of Heating, Refrigerating and Air-Conditioning Engineers is the world's foremost technical society in the fields of heating, ventilation, air conditioning, and refrigeration. Its members worldwide are individuals who share ideas, identify needs, support research, and write the industry's standards for testing and practice. The result is that engineers are better

able to keep indoor environments safe and productive while protecting and preserving the outdoors for generations to come [5].

2.2 Indoor Environmental Quality (IEQ)

Indoor environmental quality (IEQ) refers to the quality of a building's environment in relation to the health and wellbeing of those who occupy space within it. IEQ is determined by many factors, including lighting, air quality, and damp conditions. Other factors such as indoor temperatures, relative humidity, and ventilation levels can also affect how individuals respond to the indoor environment. Understanding the sources of indoor environmental contaminants and controlling them can often help prevent or resolve building-related worker symptoms. Practical guidance for improving and maintaining the indoor environment is available [2,4].

Building indoor environment covers the environmental aspects in the design, analysis, and operation of energy-efficient, healthy, and comfortable buildings. Fields of specialization include architecture, HVAC design, thermal comfort, indoor air quality (IAQ), lighting, acoustics, and control systems [2].

2.2.1 Environment in Residential buildings

According to Standard, ASHRAE [6], thermal comfort is defined as the state of mind that expresses satisfaction with the thermal environment in which it is located .These standards are used as benchmarks by designers of buildings world - wide.

Indoor air quality (IAQ) is an important issue that has both short term and long term impacts on the health of occupants [7]. There are two common strategies

in building design that are employed to deal with the IAQ in a building. The first one is to improve the indoor air quality by increasing the ventilation rate, which in turn reduces air pollutant [8]. The second is by reducing the source of pollution within and outside the building in order to reduce the introduction of pollutants in the indoor air .

2.2.2 Environment in Industries

Many ecological studies have revealed that extremely hot weather contributes to excess morbidity and mortality in the community [9]. Most of the extreme heat-related research has traditionally focused on vulnerable populations including the elderly, children and patients with chronic diseases and those on certain medications[9]. Extremely hot weather also places many types of indoor and outdoor manual workers at increasing risk of heat-related illnesses and injuries [10,11]. Increased concerns about the environmental heat-related impacts of climate change on population health have been raised since the late 1990s.Heat gain can be a combination of external heat from the environment and internal body heat generated from metabolic processes. There are two types of external heat exposure sources in the workplace: weather-related and man-made heat exposure. With predicted increasing frequency and intensity of heat waves, weather-related heat exposure is presenting a growing challenge to occupational health and safety[9].

2.2.3 Agricultural workers

Agriculture is one of the industries at highest risk of heat-related illness and injury. Farmers are often exposed to outdoor heat extremes for long periods of time, and often there is a lack of occupational health and safety programs. In the US, agricultural industries have the third highest rate of heat-related deaths among all industries, with a mortality rate approximately 20 times greater than for all civilian workers [9] In terms of heat-related morbidity, farm workers have been shown to be four times more likely than non-agricultural workers to suffer from heat-related illnesses in the US [12].

By reviewing medical records, and found that 45% occurred among farmers. In another study by the same author, it was found that approximately 94% of farmers reported working in extreme heat, among which 40% experienced heat stress related symptoms [13] . At the time no regulations and prevention measures were available for preventing heat exposure. A study of 124 Japanese forestry workers showed that 32.3% had reported symptoms of heat illness [9]. With low levels of mechanized farming and motivation by payment based on work output, agricultural workers in low-middle income countries may be at relatively higher risk of heat exposure [14,15] .

2.2.4 Construction workers

In the building industry, several contributing factors increase the risk of heat-related illness and injury. These include the constant use of machinery and powered tools, working on elevated surfaces, heavy workload, simple accommodation conditions near work sites,. Those symptoms are consistent with the hypothesis that heat exposure may increase the risk of occupational accidents and injuries. In Taiwan [16] and Thailand [17], temporarily self-employed construction workers reported suffering from severe heat strain because of physically demanding work and hot accommodation conditions in dormitories near construction sites.

However, if preventive measures are sufficient in building sites, workers could avoid heat-related symptoms. A cross-sectional study has been conducted among 12 male workers in a Japanese hydroelectric power plant building site with WBGT often exceeding the recommended exposure limit values most of the time on a typical hot day in summer [18]. However, there was no significant change in subjective symptoms, serum electrolytes, blood pressures and heart rates before and after work, because preventive measures had been taken. These included temporary tents for rest, electric fans for ventilation, and automatic machines for cool drinks. But there should be caution in the interpretation of the results because of the small sample size and the fine weather conditions during the two days investigation period. Apart from common preventive measures, self-pacing can also be an effective way of reducing the risk of heat-related illness and injury as reported in a study of construction workers in the United Arab Emirates [19].

2.2.5 Manufacturing workers

Manufacturing workers in non-air conditioned indoor workplaces are also at risk of heat-related illness despite little or no direct sunlight radiation. The levels of heat stress can be very high in workplaces surrounding hot machines, furnaces, ovens, and molten metal. Even in winter, the temperatures near furnaces in a steel plant have ranged from 35.5 to 46.5°C when the outdoor temperature was only 14–18°C [9]. Increased hot days due to climate change may worsen the extent of heat stress for individuals working around heat generating sources. Hence, many epidemiological studies have focused on the impacts of workplace-generated heat on factory workers in steel plants [20,21], foundries [22], automobile industries [23,24], and glass manufacturing units [25].

Excessive industrial heat exposure is associated with cardiovascular and digestive diseases [26]. However, a cohort study in a French stainless steel producing plant showed that cardiovascular disease mortality was 10% lower for the workers exposed to heat than for a control group that was not exposed [27]. The negative relationship between heat exposure and mortality may result from the 'healthy worker effect' due to the stringent selection criteria when recruiting workers .

2.2.6 Environment In School

Indoor Environment Comfort results on the combination of four major environmental factors, such as Thermal Comfort (TC), Indoor Air Quality (IAQ), Acoustic Comfort (AC) and Visual Comfort (VC) [28]. Thermal comfort in schools (classrooms) has lately been receiving more research attention [29 - 32]. Either because indoor environmental quality(IEQ) has a repercussion on buildings'

energy use [30] but also because this might condition students and teachers performance [33 - 39].

The educational environment in the 21st century schools has become the focus of educators' attention and how to prepare it to achieve educational goals in several areas that serve the entire school community. The school community must provide an educational environment with values, principles and positive practices that constitute a new school culture. It contains a system of values, customs, traditions and positive practices by the members of the school community, where the educational environment is not limited to the process of education only, as it takes into account the educational process and serve the environment of the student and the environment of education and Science, health and safe environment, and the use of modern educational methods [40].

healthy school environment includes the physical and aesthetic surroundings and the psychosocial climate and culture of the school. Factors that influence the physical environment include the school building and the area surrounding it, biological or chemical agents, and physical conditions such as temperature, noise and lighting. The psychological environment includes the physical, emotional and social conditions that affect the well-being of students and staff [41].

For ease in understanding, this section is divided into two components that together comprise an overall and comprehensive healthy school environment. :

(1) social emotional school environment .

(2) physical school environment.

Students who attend schools with a positive, respectful climate are able to focus on learning and realize their academic, interpersonal and athletic potential[42] .

A positive school climate results in positive outcomes for school personnel as well. Characteristics of school climate, especially trust, respect, mutual obligation and concern for others' welfare, can have powerful effects on educators' and learners' interpersonal relationships[43]. Safe, collaborative learning communities where students feel safe and supported report increased teacher morale, job satisfaction, and retention. The interaction of various characteristics of school and classroom climate can create a fabric of support that enables all members of the school community not only to learn but also to teach at optimum levels [44]. Conversely, a negative school climate interferes with learning and development.

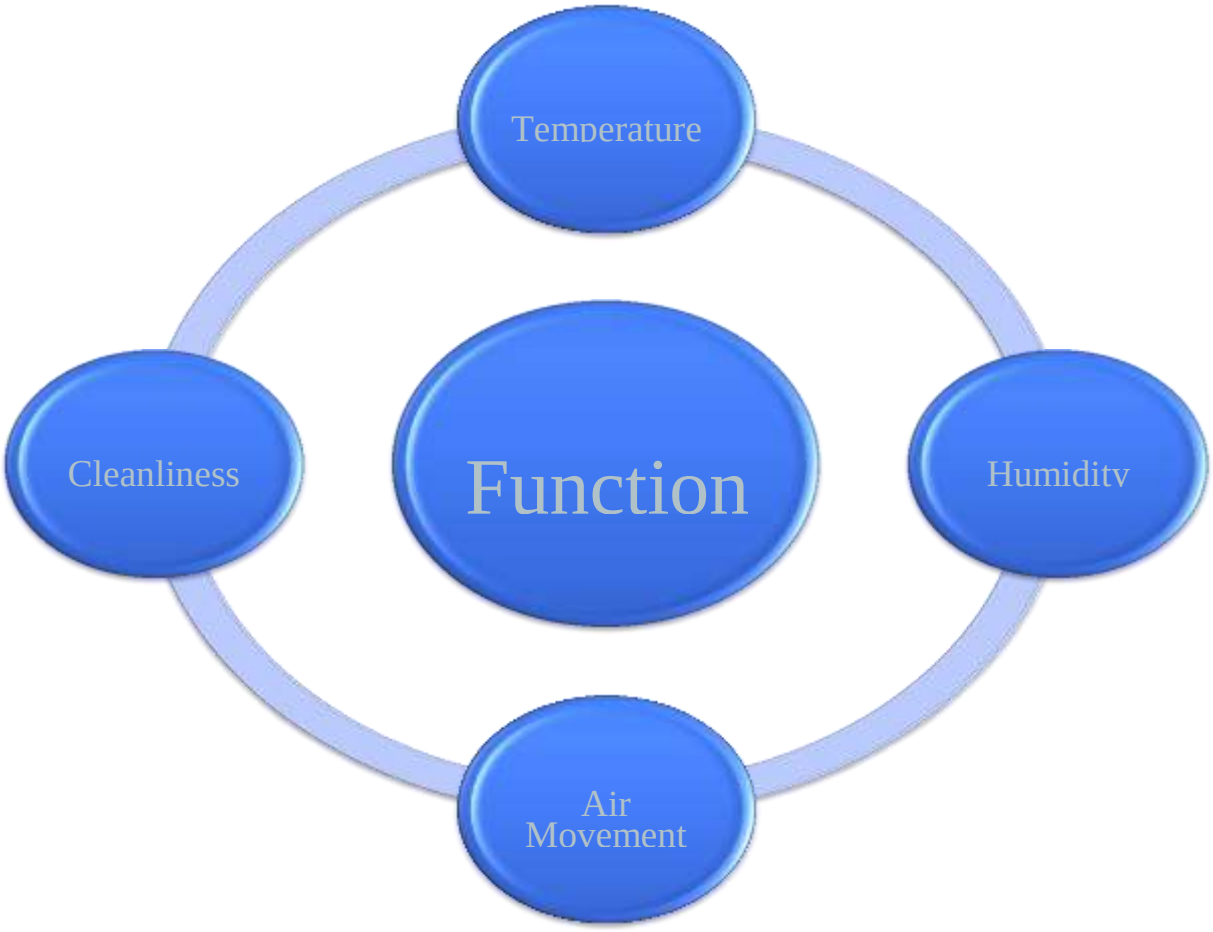
2.3 Impacts of Workplace Heat Exposure on Selected Susceptible Occupations

Without adequate heat dissipation, short-term acute extreme heat exposure can cause a rise in core body temperature and may result in direct heat illnesses. Adverse long-term health effects of chronic workplace heat exposure have also been reported such as cardiovascular diseases [22], mental health problems [45,46], and chronic kidney diseases [47] . In addition to work-related illnesses , workplace heat exposure can also increase the risk of occupational injuries and accidents. Core temperature elevation and dehydration have had negative behavioral effects such as physical fatigue, irritability, lethargy, impaired judgment, vigilance decrement, loss of dexterity, coordination and concentration [48], potentially leading to a compromise of occupational safety.

2.4 Methods of Air conditioning

Air conditioning (often referred to as AC, A.C., or A/C) is the process of removing heat from a confined space, thus cooling the air, and removing humidity. Air conditioning can be used in both domestic and commercial environments. This process is most commonly used to achieve a more comfortable interior environment, typically for humans or animals; however, air conditioning is also used to cool/dehumidify rooms filled with heat-producing electronic devices, such as computer servers, power amplifiers, and even to display and store artwork[49].

Air conditioners often use a fan to distribute the conditioned air to an occupied space such as a building or a car to improve thermal comfort and indoor air quality. Electric refrigerant-based AC units range from small units that can cool a small bedroom, which can be carried by a single adult, to massive units installed on the roof of office towers that can cool an entire building. The cooling is typically achieved through a refrigeration cycle, but sometimes evaporation or free cooling is used [50].



Figure(2.1) : Functions of air conditioning[60]

2.4.1 Evaporative cooling

Evaporative air-conditioning (EAC) technologies are being used increasingly in residential and commercial applications worldwide. EAC technologies-which rely on water as a coolant rather than on chemical refrigerants-are economical to produce and use and have important environmental benefits. This paper introduces the technical aspects of EAC, reviews EAC's scope of application, and surveys the specific climatic conditions under which EAC can be used most effectively in industrialized and developing countries [52].

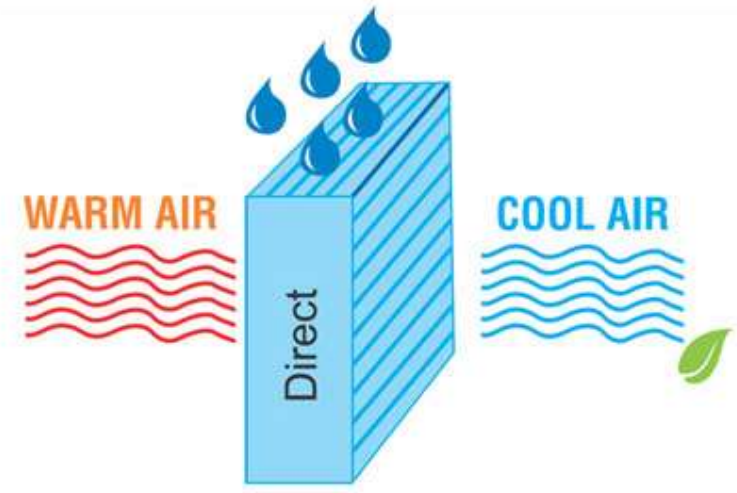
Evaporative cooling is most effective when the relative humidity is on the low side, limiting its popularity to dry climates. Evaporative cooling raises the internal humidity level significantly. The two most important climate considerations are dry-bulb temperature and wet-bulb temperature.

A general recommendation for applying direct evaporative cooling is to implement it in places where the wet-bulb temperature of the outdoor air does not exceed 22 °C (71.6 °F) [51]. These coolers cost less and are mechanically simple to understand and maintain [53].

2.4.1.1 Types of evaporative cooling

1- Direct Evaporative Air-Conditioning **:**

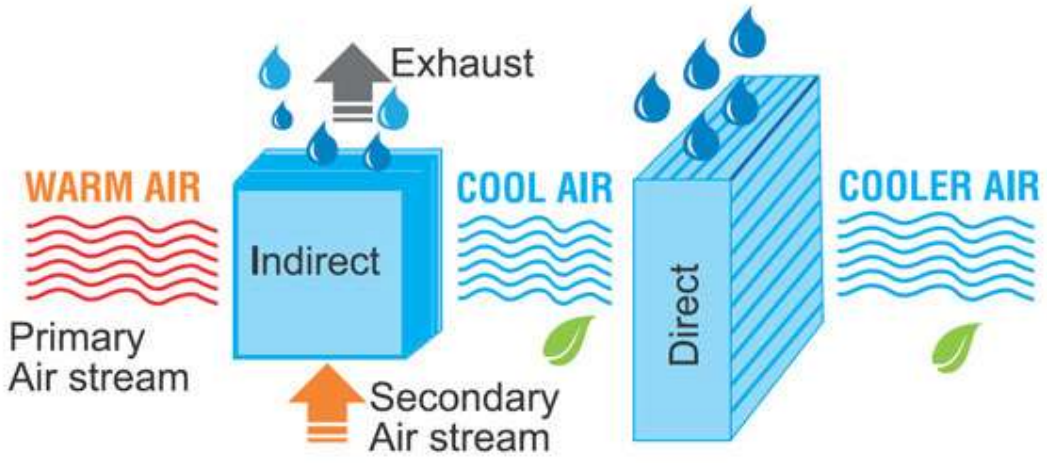
Direct EAC is the simplest, the oldest, and the most widespread form of air-conditioning. This system typically uses a fan to draw hot outside air into a dwelling through a porous wetting medium. Heat is absorbed by the water as it evaporates from the porous wetting medium, and the air thus leaves the EAC at a lower temperature[52].



Figure(2.2): Direct Evaporative Air-Conditioning[52]

2- Indirect Evaporative Air-Conditioning **:**

Indirect-direct EAC is a method established only over the past 15 years. It is not as widely used as direct EAC, but it is gaining in popularity because it cools air more than direct EAC, and cools the air down from higher wet-bulb temperatures. indirect EAC accomplishes these effects by building an additional step into the cooling process. That is , the incoming air is cooled first with a normal air-to--air heat exchanger. This is the "indirect" stage because it does not add moisture to the supply air. Instead, only one side of the heat exchanger is cooled with evaporating water as the supply air passes through the other side, dropping in temperature as it does. Only then, as it passes through the direct EAC stage, is the supply air moisturized. The final air leaving an indirect-direct EAC unit is generally 3.5C (6.3 0F) cooler than what could be achieved with a direct EAC unit alone. Because it cools the air first without moisturizing it, the indirect-direct process also allows the EAC unit to provide more comfort in slightly more humid areas[52].



Figure(2.3) : Indirect Evaporative Air-Conditioning[52]

2-4-1-2 Performance

For direct evaporative cooling, the direct saturation efficiency, ϵ , measures in what extent the temperature of the air leaving the direct evaporative cooler is close to the wet-bulb temperature of the entering air. The direct saturation efficiency can be determined as follow [40] .

$$\epsilon = \frac{T_{e,db} - T_{l,db}}{T_{e,db} - T_{e,wb}}$$

Where:

ϵ= direct evaporative cooling saturation efficiency (%)

$T_{e,db}$= entering air dry-bulb temperature (°C)

$T_{l,db}$= leaving air dry-bulb temperature (°C)

$T_{e,wb}$= entering air wet-bulb temperature (°C)

2-4-1-3 Benefits of Evaporative Cooling:

The following benefits of EAC can be cited:

1- Reduced CO_2 and power plant emissions

2- Improved indoor air quality

3- Life cycle cost effectiveness

4- Provide humidification when needed

5- Easy to use with direct digital control (DDC)

6- Substantial energy and cost savings

2.4.2 Window air conditioner

Window air conditioner is the most commonly used air conditioner for single rooms. In this air conditioner all the components, namely the compressor, condenser, expansion valve or coil, evaporator and cooling coil are enclosed in a single box. This unit is fitted in a slot made in the wall of the room, or more commonly a window sill [54].

2.5 Current studies in indoor

poor ventilation rates in classrooms significantly impair children's attention and vigilance. The faster and more accurate responses in Choice RT and color . Word Vigilance tasks reflect higher level of focused attention at higher ventilation rates compared to low rates with natural ventilation. In poorly ventilated classrooms, students are likely to be less attentive and to concentrate less well on instructions given by teachers. The magnitude of the negative effects with inadequate ventilation was even higher for tasks that require more complex skills such as spatial working memory and verbal ability to recognize words and non-words. Ventilation rates in the order of 8 l/s per person are recommended in all teaching facilities to prevent any impairment of pupils' performance due to inadequate ventilation. Additionally, it was demonstrated in one of the schools which had good ventilation background that pupils reacted significantly faster in a number of simple tasks when the classroom temperatures were reduced from

existing slightly elevated levels to a more comfortable range. The present findings are in good agreement with the results reported by a number of other independent studies investigating the effects of classroom environmental quality on pupils' learning performance . Based on the outcomes and observations made during the investigations in the 8 UK schools which involved feedback from teachers, the present study proposes the following suggested recommendations to school managers, designers and related personnel involved in school design and maintenance : suggested recommendations for UK schools managers include equipping classrooms with a device to monitor CO_2, temperature & relative humidity in classrooms and keeping temperatures within comfortable range of

20-22°C (winter) and 22-24°C (summer), avoiding moisture build up in classrooms and keeping humidity levels below 60% during winter time but preferably above 40% and creating daily windows opening routines for the school [55] .

This research focuses on the relationship between pupils health, well-being and performance, and the IAQ in classrooms of Southern England. Field surveys will be carried out at twenty different primary school buildings located near (Reading), during 2–4 weeks in the Autumn, Winter, Spring and Summer. The sample will include a selection of old and new school buildings to provide comparison. The surveys will be carried out over 2 years and efforts will be made to carry out the tests in clusters of school buildings with different ventilation styles, occupancy profiles and densities, within close geographical proximity but with different background (external) pollution levels .The objectives of this project are :

i) To determine the effect of IAQ (in terms of the concentrations of particulates and CO_2 as indicators) on pupils performance.

ii) To investigate the effects of ventilation rates and thermal comfort on pupils performance and health.

iii) To recommend suitable ventilation rates for classrooms . To examine the suitability of the air quality guidelines for classrooms .

Reduction of energy consumption is a major part of sustainable building design. There is a tendency to reduce ventilation rates and natural or hybrid ventilation systems are common in the design of UK schools , indicates that CO_2 levels can rise to very high levels in classroom occupancy periods . Further, these levels may be detrimental to concentration hence adversely affect learning [56].

The main goal of this paper is to present a set of well-defined and structured procedures to establish guidelines for the application of an integrated assessment of energy performance and indoor climate in schools. Increasing the knowledge about how energy is consumed in schools is a way to enhance the awareness of school managers (board of directors) about the importance of improving energy efficiency and reducing energy costs. The proposed methodology helps to identify major energy consuming equipment in school buildings and potential energy conservation measures.

The assessment of indoor climate identifies potential corrective measures to problems related to indoor air quality and thermal comfort, also supporting the study of further energy conservation measures associated with ensuring environmental quality. Results of a case study showed that the expected energy consumption reduction is about 11.2 % due to a better usage of day lighting and 4.5 % due to the reduction of fresh air flow rates, while extending the ventilation operation time. In addition, there is a considerable non calculated potential for energy savings and improvement of indoor environmental conditions in school buildings [57].

Investigated indoor air quality in 17 mechanically ventilated and naturally ventilated deep energy retrofits .They found statistically indistinguishable air change rates between the two house types. Furthermore, a number of faults with mechanical ventilation systems were identified, including air recirculation, clogged outside air inlets, failed attachment of ducts to units, irregular speed fluctuating from low to high and poor control [58].

Investigated the effect of energy retrofits on indoor environmental quality in sixteen apartments (eight with continuous mechanical ventilation and eight without). The finding suggest improvements in levels of carbon dioxide, VOC's, acetaldehyde, PM2.5, comfort conditions and bathroom relative humidity; however mixed results were reported for concentrations of formaldehyde and nitrogen dioxide. In general, apartments with continuous mechanical ventilation showed a greater improvement of indoor environmental quality (other than PM2.5) compared to those without [58].

Looked at the conflict between air quality and energy efficiency in social housing, with particular reference to occupant behavior. The results suggest a risk of negative impact on health from indoor air pollution in the social housing sector [58].

The study has investigated how the building's energy use and indoor environment have been changed by comparing the retrofitted and non-retrofitted building. The retrofit has shown positive effects on both energy performance and indoor environment. Though the retrofitted building's facility electricity use has been reduced by removing the common laundry, this has caused higher household electricity use. From an energy system perspective, the total energy use of the whole building has not decreased. After the retrofit, the space heating demand has been reduced by 39%, which is higher than the 2020 national goal but in order to

reach the 2050 goal, more energy efficiency measures would need to be made. The parameter study shows that reducing the indoor temperature by 1 ◦C could be one option [59].

Compares one Passive House apartment with one low-energy apartment in Vienna based on monitored indoor environmental conditions (including indoor air temperature, relative humidity and CO_2 concentration), metered energy use, calculated embodied energy, CO_2 emissions, user evaluation, and construction costs data over a period of 5 months. Meanwhile, both of two apartments were constructed simultaneously in the same location and using comparable building construction properties and floor plan. However, the major difference between them is their ventilation systems: Passive building employs controlled mechanical ventilation, whereas low-energy building applies mostly user manual natural ventilation – open/close the windows. The results demonstrate that both passive and low-energy buildings operated very well from the points of view of thermal conditions and indoor air quality etc., although the passive building performance was slightly better. It also shows that passive building consumed about 65% less heating energy and 35% less electrical energy as compared with low-energy building. In addition, CO_2 emissions of passive building were about 25–40% less than low-energy building [59].

CHAPTER THREE

CHAPTER THREE

METHODOLOGY

3.1 Introduction

In this research the method used to assessment and study the effect of indoor air quality on the students in terms of health and the level of concentration during the school day , and also renewing the air inside the buildings to get rid of air saturated with carbon dioxide or smoke and odors and the provision of a lot of oxygen, which means providing healthy air for people inside, especially in closed rooms or places that are crowded with people such as studies hall.

3.2 Location

The experimental work was carried out at Khartoum state in three schools , two of them are private schools and the other one is government school because they have different environment , and also it contained two universities .

3.3 Experimental Steps

In this research we used to measure degrees of temperature , humidity and wind speed in studies hall in different days , and we measured these degrees in two stages :

1- With mechanical ventilation (the air conditions on).

2- with national ventilation (opening the door and windows) .

the measurements were taken in different areas inside the studies hall according to the student and teacher places.

Figure (3.1) : Class in Khalid Ibn Alwaleed primary school

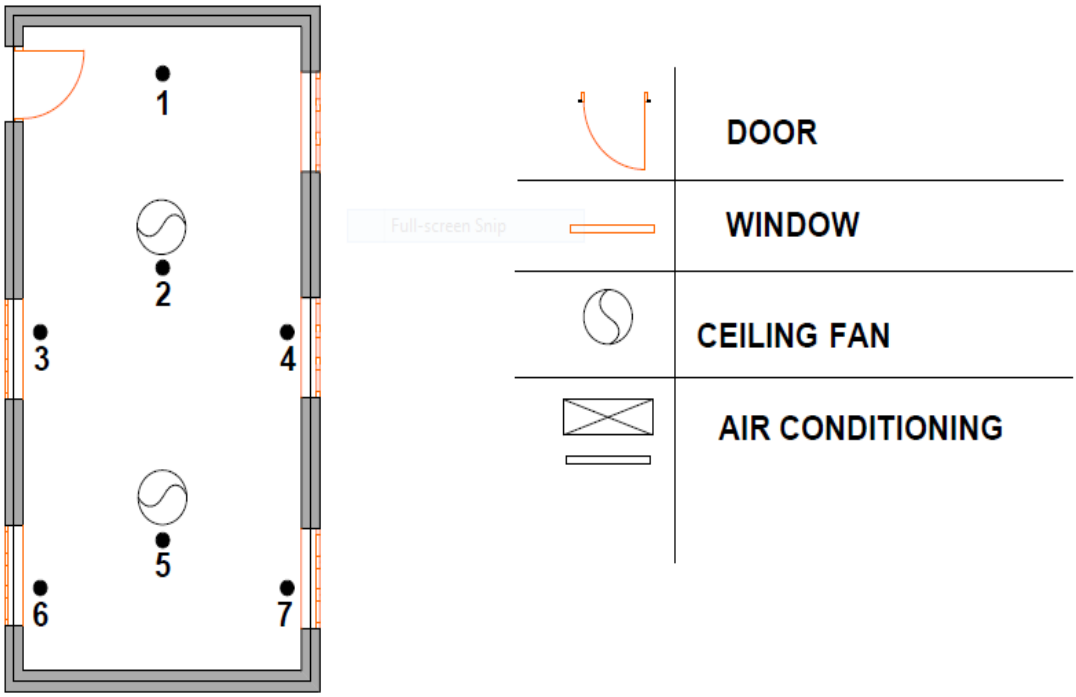


Figure (3.2) :Class in Khalid Ibn Alwaleed primary school

Figure (3.3): Class in Al.Mawahb Primary School

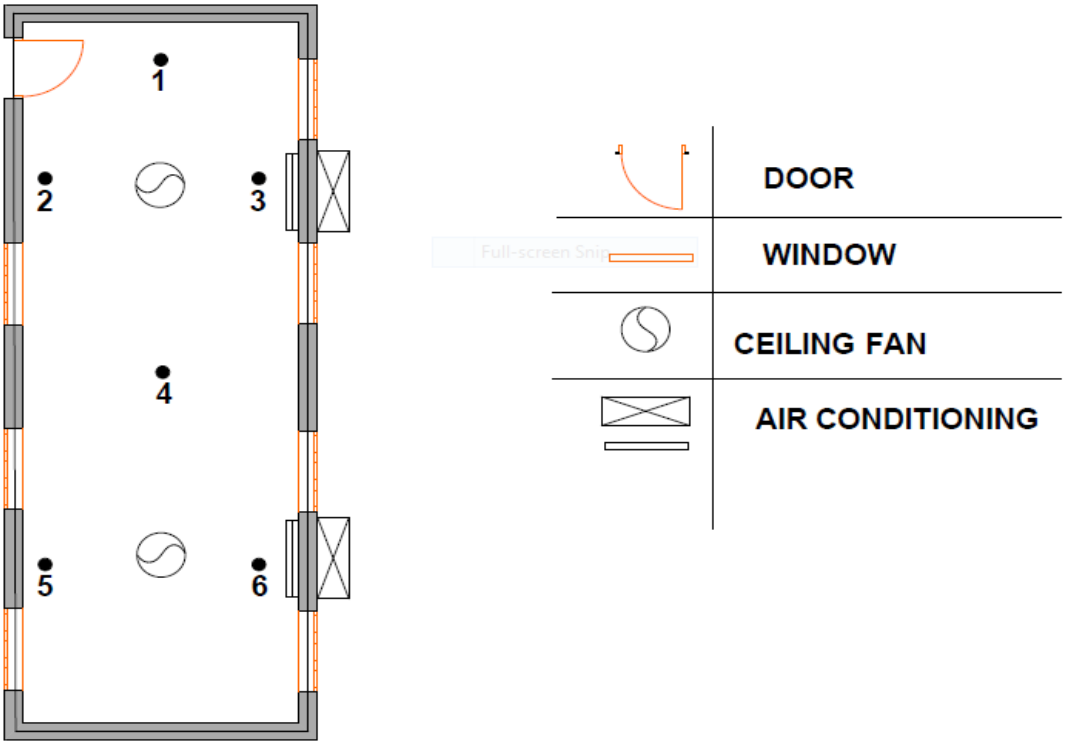


Figure (3.4): Class in Al.Mawahb Primary School

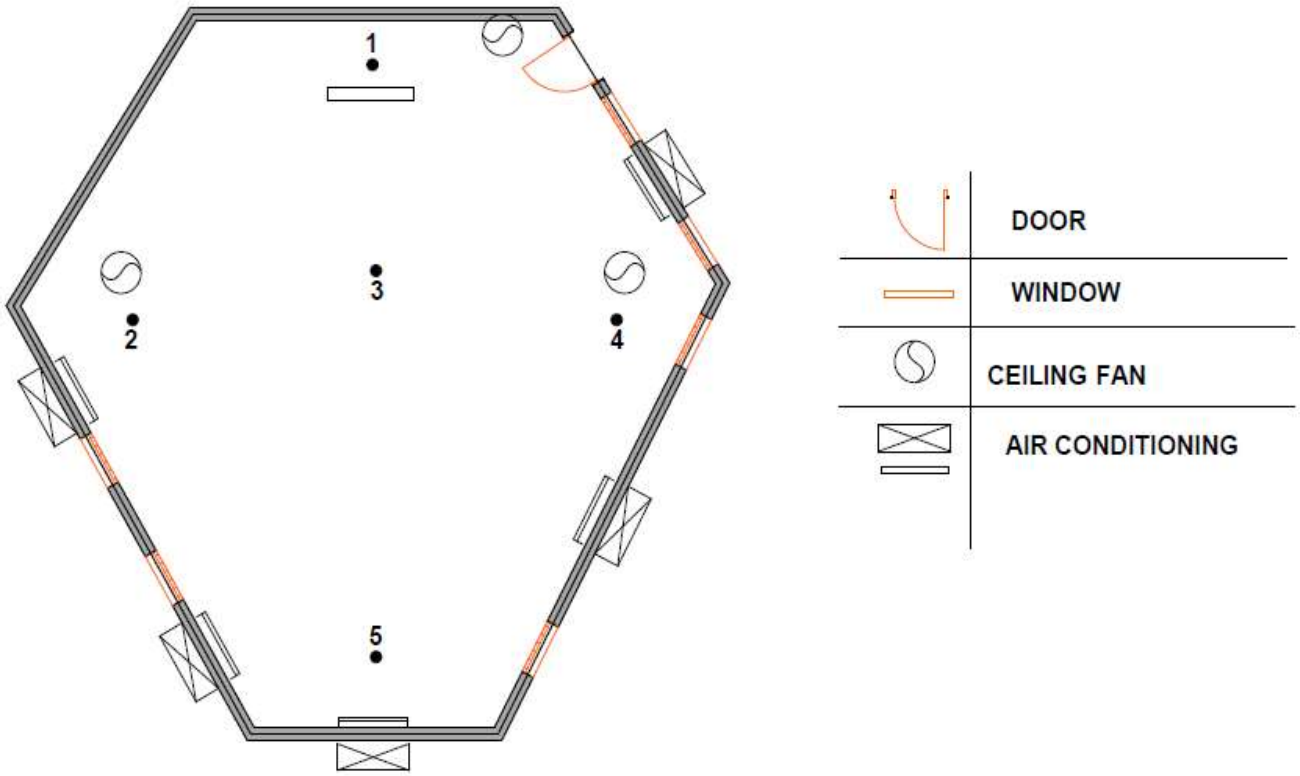


Figure (3.5) : Hall (3) in Sudan university of science and technology

3.4 Experimental Devices

In this research we used two different devices which can help us to get the measures inside and outside the studies hall and they are :

i) Animometer

ii) digital devices to measure the temperature and humidity

3.4.1 Animometer

An anemometer is a device used for measuring the speed of wind, and is also a common weather station instrument. The term is derived from the Greek word (anemos), which means wind, and is used to describe any wind speed measurement instrument used in meteorology.

Figure (3.6): The digital Animometer

3.4.2 Hygro-Thermometer

A hygrometer is a chart recorder that measures and records both of temperature and humidity (or dew point). Similar devices that record only one parameter are a thermograph for temperature and hygrograph for humidity . Also this device can record the Maximum and Minimum and also the inside and outside temperature and humidity value automatically.

Figure (3.7):The digital hygrometer

3.5 Experimental Procedures

The measures were taken in different locations inside the class depends on the locations of the students and teachers and Figure (3.3),(3.4) shows the devices that we used to measures the degrees of temperature ,humidity and wind speed inside the class .The experiment was repeated several times in different days and the average value was calculated to the final measures .

CHAPTER

FOUR

CHAPTER FOUR

RESULTS AND DISCUSSION

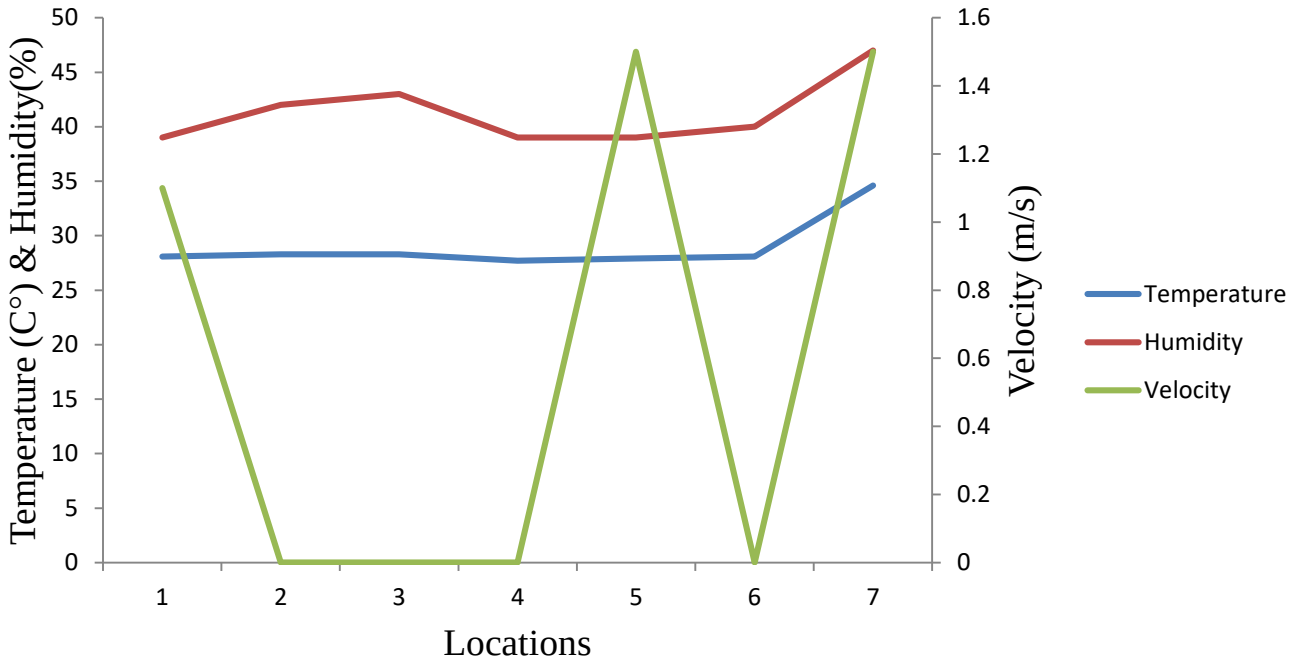
4.1 Introduction

This chapter presents the results of an experimental setup. These results show the temperature, humidity and air velocity during the day . All data presented in this studies were an average value taken from five repeated experiments at the same conditions .

4.2 Results Analysis

The experiment was achieved and repeated several times and the average value was calculated for them .

4-2-1 Class in Al-Mawahb Primary School



Figure(4.1) : Class in Al.Mawahb primary School A.C is on

From figure (4.1) the X-axis shows the locations inside the class and the left Y-axis shows temperature and humidity and the right Y-axis shows the air velocity .The air conditions were working and the internal temperature is suitable for study and change between (27.7 - 28.3 Cº) and the ambient temperature were found about (34.6Cº) , however the distribution of air is not good because of the wrong position of ventilation and air conditioning devices , and the number of students are 35 .

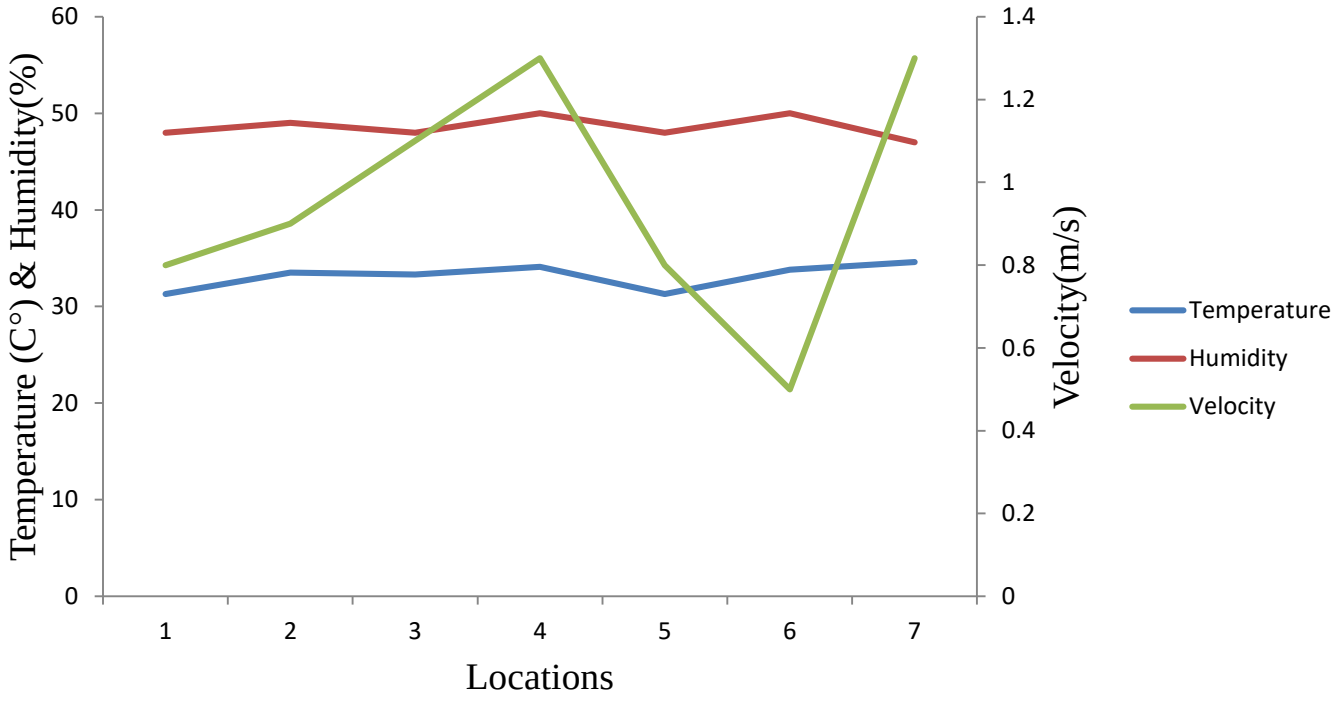
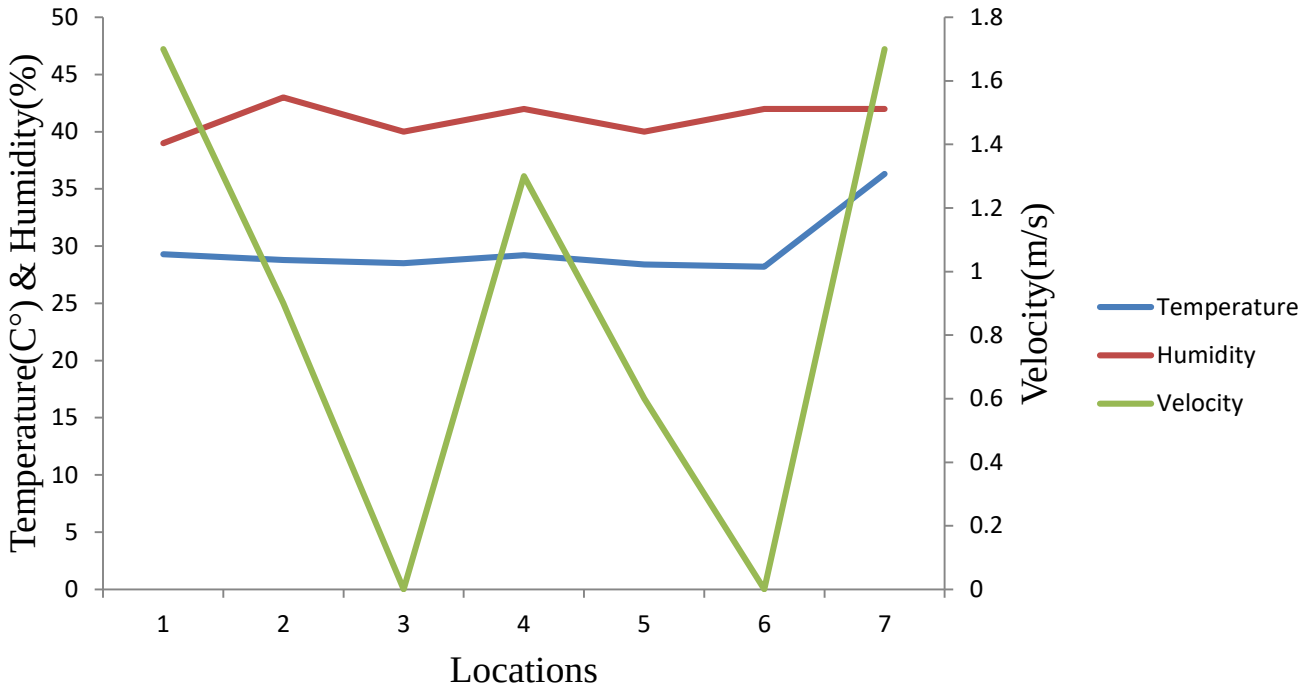


Figure (4.2) : Class in Al.Mawahb Primary School A.C is off

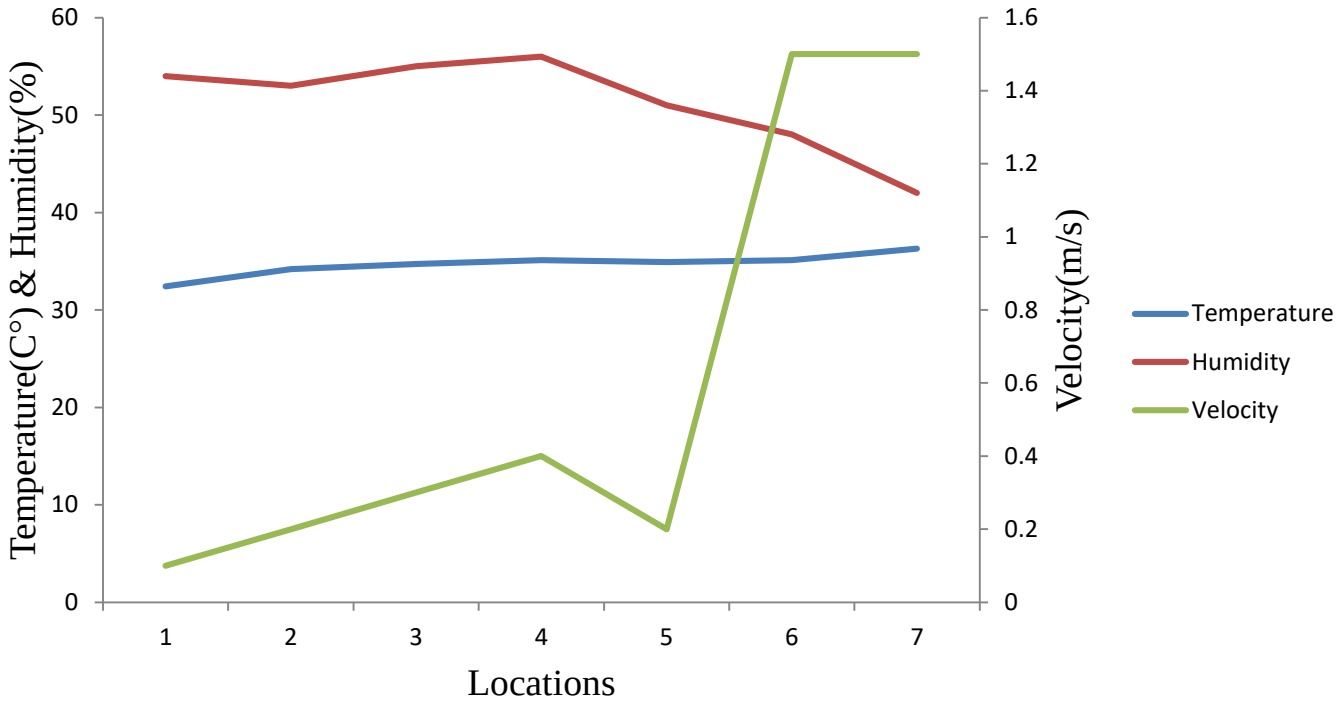
From figure (4.2) the X-axis shows the locations inside the class and the left Y-axis shows temperature and humidity and the right Y-axis shows the air velocity .The air conditions were not working and it is noticeable here that the temperature and humidity are remarkably high , and the velocity of air is not constant depends on the outside air .

4-2-2 Class in Al-Mawahb Secondary School



Figure(4.3) : Class in Al.Mawahb Secondary School A.C is on

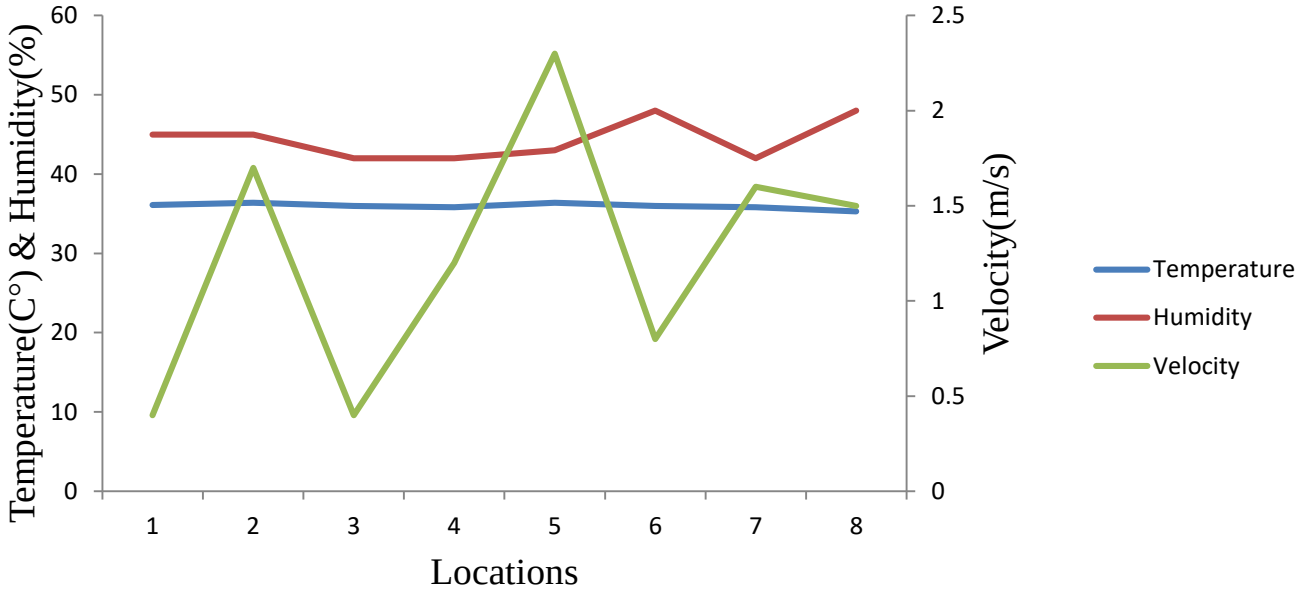
From figure (4.3) the X-axis shows the locations inside the class and the left Y-axis shows temperature and humidity and the right Y-axis shows the air velocity . The air conditions were working and the temperature of the room are almost constant where they change at the rate between (28.2 - 29.3 Cº) and the ambient temperature were found about (36.3Cº) , although the internal temperature is suitable for study but the distribution of air is moderate as students below the air conditioning are not exposed to enough air , and the humidity rate between (40 - 43%) and it depends on the outside atmosphere and the number of students , and the number of students are 32 .



Figure(4.4) : Class in Al.Mawahb Secondary School A.C is off

From figure (4.4) the X-axis shows the locations inside the class and the left Y-axis shows temperature and humidity and the right Y-axis shows the air velocity . The air conditions were not working and also it is noticeable here that the temperature and humidity are remarkably high .

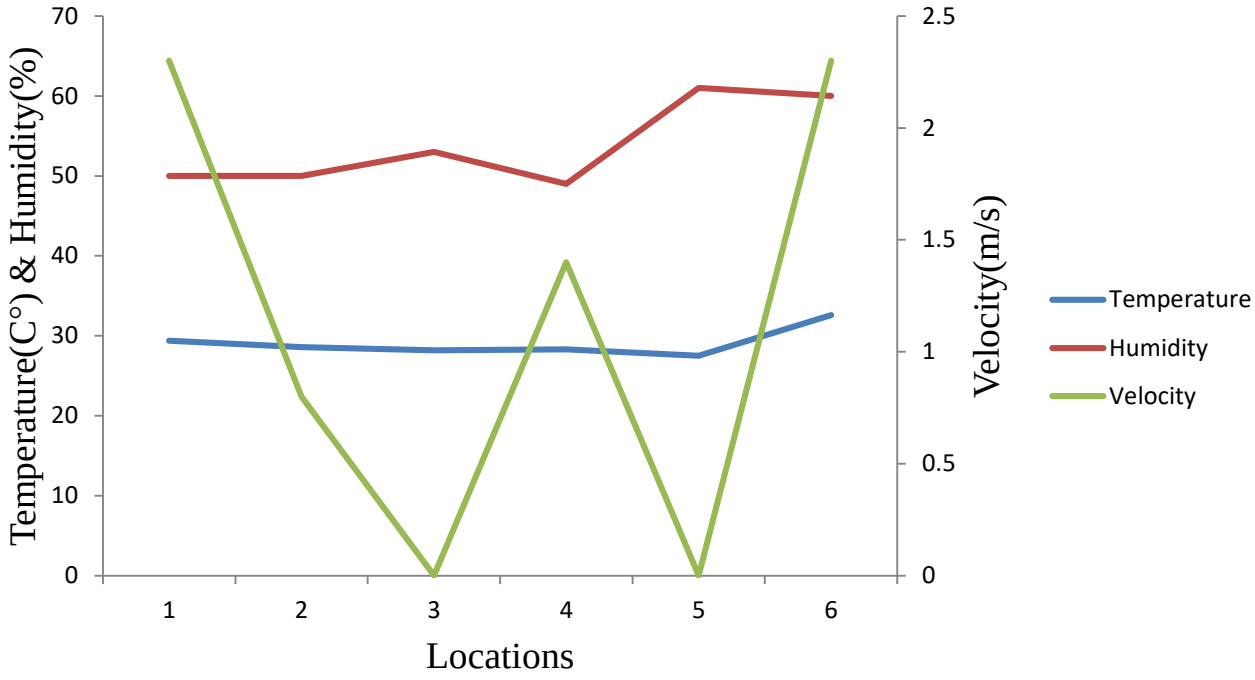
4-2-3 Class in Khalid Ibn Alwaleed primary school



Figure(4.5) : Class in Khalid Ibn Alwaleed primary school

From figure (4.5) the X-axis shows the locations inside the class and the left Y-axis shows temperature and humidity and the right Y-axis shows the air velocity . In this class there is no air conditioning devices and the class environment is not suitable to study because the temperature rate between (35.8 - 36.4 Cº) and it is very high and the ambient temperature is (35.3 Cº) and it is noticeable that the temperature inside the class is higher than the outside temperature , and also the humidity rate between (41 - 45%) .

4-2-4 Hall (3) in Sudan University of science and technology



Figure(4.6) : Hall (3) in Sudan University A.C is on

From figure (4.6) the X-axis shows the locations inside the hall and the left Y-axis shows temperature and humidity and the right Y-axis shows the air velocity , the temperature and humidity is high because the air conditioning devices are few compared to the size of the large hall , also the distribution of air is not suitable inside the hall .

CHAPTER

FIVE

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Indoor environmental quality (IEQ) refers to the quality of a building's environment in relation to the health of those who occupy space within it . IEQ is determined by many factors, including, air quality, temperature , humidity and ventilation levels can also affect how individuals respond to the indoor environment . The healthy educational environment is very important for students inside the studies hall and it is important for their health and concentration during the study day.

From this experimental study in schools and universities it was found that the majority of schools environment is not suitable for students and study. These experiments were done in different places and the results were found to be close,

for example in Al-Mawahb primary school the range of temperature when A.C were working and when A.C were not working is high , and also in Al-Mawahb secondary school the range of temperature when the A.C were working and when A.C were not working is high and not suitable .

5.2 Recommendations

The followings are the conclusive remarks and recommendations for further studies in this direction :

1- Providing a healthy environment for students because human resources are the most important sources of development for the country

2- Use insulating materials for heat-in-construction material such as PCM and using zero energy building in school.

3- In the next experimental study, a device can be used to measure the ratio of CO_2 by using gas analyzer.

Reference

1.Stephan, Constantin. "Industrial health, safety and environmental management." *Muenster: MV Wissenschaft* (2012): 26-28.

2. FIGHTING, FIRE. "The National Institute for Occupational Safety and Health (NIOSH)." *Signal* 52: 53-59.

3. Sieminski, Adam. "International energy outlook." *Energy Information Administration (EIA)* (2014).

4. Yu, Chuck WF, and Jeong Tai Kim. "Building environmental assessment schemes for rating of IAQ in sustainable buildings." *Indoor and Built Environment* 20.1 (2011): 5-15.

5-Handbook, A. S. H. R. A. E. "Fundamentals." *American Society of Heating, Refrigerating and Air Conditioning Engineers, Atlanta* 111 (2001).

6. Djongyang, Noël, René Tchinda, and Donatien Njomo. "Thermal comfort: A review paper." *Renewable and Sustainable Energy Reviews* 14.9 (2010): 2626-2640.

7. Wargocki, Pawel, et al. "Ventilation and health in non-industrial indoor environments: report from a European Multidisciplinary Scientific Consensus Meeting (EUROVEN)." *Indoor air* 12.2 (2002): 113-128.

8. Daisey, Joan M., William J. Angell, and Michael G. Apte. "Indoor air quality, ventilation and health symptoms in schools: an analysis of existing information." *Indoor air* 13.1 (2003): 53-64.

9. Xiang, Jianjun, et al. "Health impacts of workplace heat exposure: an epidemiological review." *Industrial health* 52.2 (2014): 91-101.

10. Bi, Peng, et al. "The effects of extreme heat on human mortality and morbidity in Australia: implications for public health." *Asia Pacific Journal of Public Health* 23.2_suppl (2011): 27S-36S.

11. Schulte, Paul A., and HeeKyoung Chun. "Climate change and occupational safety and health: establishing a preliminary framework." *Journal of occupational and environmental hygiene* 6.9 (2009): 542-554.

12. Koruk, I., et al. "Intestinal parasites, nutritional status and physchomotor development delay in migratory farm worker's children." *Child: Care, Health and Development* 36.6 (2010): 888-894.

13. Arcury, Thomas A., and Sara A. Quandt. "Living and working safely: Challenges for migrant and seasonal farmworkers." *North Carolina medical journal* 72.6 (2011): 466.

14. Xiang, Jianjun, et al. "Perceptions of workplace heat exposure and controls among occupational hygienists and relevant specialists in Australia." *PloS one* 10.8 (2015): e0135040.

15. Xiang, Jianjun, et al. "The impact of heatwaves on workers′ health and safety in Adelaide, South Australia." *Environmental research* 133 (2014): 90-95.

16. Lin, Ro-Ting, and Chang-Chuan Chan. "Effects of heat on workers' health and productivity in Taiwan." *Global Health Action* 2.1 (2009): 2024.

17. Yoopat, Pongjan, et al. "Ergonomics in practice: physical workload and heat stress in Thailand." *International journal of occupational safety and ergonomics* 8.1 (2002): 83-93.

18. Morioka, Ikuharu, Nobuyuki Miyai, and Kazuhisa Miyashita. "Hot environment and health problems of outdoor workers at a construction site." *Industrial health* 44.3 (2006): 474-480.

19. Bates, Graham P., and John Schneider. "Hydration status and physiological workload of UAE construction workers: A prospective longitudinal observational study." *Journal of Occupational Medicine and Toxicology* 3.1 (2008): 21.

20. Fogleman, Maxwell, Layla Fakhrzadeh, and Thomas E. Bernard. "The relationship between outdoor thermal conditions and acute injury in an aluminum smelter." *International journal of industrial ergonomics* 35.1 (2005): 47-55.

21. Fujii, Ronaldo Kenzou, et al. "Heat exposure control using non-refrigerated water in Brazilian steel factory workers." *Industrial health* 45.1 (2007): 100-106.

22. Vangelova, Katia, Christo Deyanov, and Michaela Ivanova. "Dyslipidemia in industrial workers in hot environments." *Central European journal of public health* 14.1 (2006).

23. Ayyappan, Ramalingam, et al. "Work-related heat stress concerns in automotive industries: a case study from Chennai, India." *Global Health Action* 2.1 (2009): 2060.

24. Venugopal, Vidhya , et al. "Occupational heat stress profiles in selected workplaces in India." *International journal of environmental research and public health* 13.1 (2015): 89.

25. Srivastava, A., et al. "Heat exposure study in the workplace in a glass manufacturing unit in India." *Annals of occupational hygiene* 44.6 (2000): 449-453.

26. Crandall, C. G., and J. Gonzalez-Alonso. "Cardiovascular function in the heat-stressed human." *Acta Physiologica* 199.4 (2010): 407-423.

27. Wild, Pascal, et al. "Mortality from cardiovascular diseases among potash miners exposed to heat." *Epidemiology* (1995): 243-247.

28. Dijken, Froukje van, et al. "Indoor environment and energy efficiency in schools." (2010).

29. Corgnati, Stefano Paolo, Marco Filippi, and Sara Viazzo. "Perception of the thermal environment in high school and university classrooms: Subjective preferences and thermal comfort." *Building and environment* 42.2 (2007): 951-959.

30. Corgnati, Stefano Paolo, Roberta Ansaldi, and Marco Filippi. "Thermal comfort in Italian classrooms under free running conditions during mid seasons: assessment through objective and subjective approaches." *Building and Environment* 44.4 (2009): 785-792.

31. Pereira, L. Dias, Edna Cardoso, and M. Gameiro da Silva. "Indoor air quality audit and evaluation on thermal comfort in a school in Portugal." *Indoor and Built Environment* 24.2 (2015): 256-268.

32. de Carvalho, Paulo Matos, Manuel Gameiro da Silva, and João Esteves Ramos. "Influence of weather and indoor climate on clothing of occupants in naturally ventilated school buildings." *Building and environment* 59 (2013): 38-46.

33. L. Baker and H. Bernstein, “The Impact of School Buildings on Student Health and Performance: A Call for Research Authors,” *McGraw-Hill Res. Found. Cent. Green Sch. U.S. Green Build. Counc.*, p. 35, 2012.

34. Issa, M. H., et al. "Absenteeism, performance and occupant satisfaction with the indoor environment of green Toronto schools." *Indoor and Built Environment* 20.5 (2011): 511-523.

35. Barrett, Peter, et al. "A holistic, multi-level analysis identifying the impact of classroom design on pupils' learning." *Building and Environment* 59 (2013): 678-689.

36. Bakó-Biró, Zs, et al. "Ventilation rates in schools and pupils' performance." *Building and Environment* 48 (2012): 215-223.

37. Kameda, Ken-ichi, et al. "Study on productivity in the classroom (part 3) nationwide questionnaire survey on the effects of IEQ on learning." *Clima 2007 WellBeing Indoors* 2006 (2007).

38. Pereira, Luísa Dias, et al. "Assessment of indoor air quality and thermal comfort in Portuguese secondary classrooms: methodology and results." *Building and environment* 81 (2014): 69-80.

39. Lee, M. C., et al. "Student learning performance and indoor environmental quality (IEQ) in air-conditioned university teaching rooms." *Building and Environment* 49 (2012): 238-244.

40. Brown, John Seely. "New learning environments for the 21st century: Exploring the edge." *Change: The magazine of higher learning* 38.5 (2006): 18-24.

41. Allensworth, Diane. "Improving the health of youth through a coordinated school health programme." *Promotion & education* 4.4 (1997): 42-47.

42. Wells, Jane, Jane Barlow, and Sarah Stewart-Brown. "A systematic review of universal approaches to mental health promotion in schools." *Health Education* 103.4 (2003): 197-220.

43. Blakemore, Sarah-Jayne, and Uta Frith. *The learning brain: Lessons for education*. Blackwell publishing, 2005.

44. Freiberg, H. Jerome. "Measuring School Climate: Let Me Count the Ways." *Educational leadership* 56.1 (1998): 22-26.

45. Tawatsupa, Benjawan, et al. "The association between overall health, psychological distress, and occupational heat stress among a large national cohort of 40,913 Thai workers." *Global health action* 3.1 (2010): 5034.

46. Smith, D. L., et al. "The effects of different thermal environments on the physiological and psychological responses of firefighters to a training drill." *Ergonomics* 40.4 (1997): 500-510.

47. Tawatsupa, Benjawan, et al. "Association between heat stress and occupational injury among Thai workers: findings of the Thai Cohort Study." *Industrial health* 51.1 (2013): 34-46.

48. Kjellstrom, Tord, et al. "Occupational heat effects: A global health and economic threat due to climate change." *Climate Change and Global Health; CAB International: Wallingford, UK* (2014): 38-44.

49. McDowall, Robert. *Fundamentals of HVAC systems*. Academic Press, 2006.

50. McDowall, Robert. *Fundamentals of HVAC systems*. Academic Press, 2006.

51. Givoni, Baruch. *Passive low energy cooling of buildings*. John Wiley & Sons, 1994.

52. Bom, Gert Jan, ed. *Evaporative air-conditioning: applications for environmentally friendly cooling*. Vol. 23. World Bank Publications, 1999.

53. Badaya, Bhavesh, et al. "SKITRON AQUA COOL DESERTER." *Imperial Journal of Interdisciplinary Research* 3.5 (2017).

54. Currier, John. *Air conditioning*. Spring term, 1966.

55. Bakó-Biró, Zs, et al. "Ventilation rates in schools and pupils' performance." *Building and Environment* 48 (2012): 215-223.

56. Clements-Croome, Derek J., et al. "Ventilation rates in schools." *Building and Environment* 43.3 (2008): 362-367.

57. Bernardo, Hermano, et al. "An approach for energy performance and indoor climate assessment in a Portuguese school building." *Sustainable Cities and Society* 30 (2017): 184-194.

58. McGill, Gráinne, Lukumon O. Oyedele, and Keith McAllister. "Case study investigation of indoor air quality in mechanically ventilated and naturally ventilated UK social housing." *International Journal of Sustainable Built Environment* 4.1 (2015): 58-77.

59. McGill, Gráinne, Lukumon O. Oyedele, and Keith McAllister. "Case study investigation of indoor air quality in mechanically ventilated and naturally ventilated UK social housing." *International Journal of Sustainable Built Environment* 4.1 (2015): 58-77.

60- Arora, Ramesh Chandra. *Refrigeration and air conditioning*. PHI Learning Pvt. Ltd., 2010.