THE RELATIONSHIP BETWEEN INDOOR AIR QUALITY AND INDOOR ENVIRONMENTAL QUALITY WITH OCCUPANTS' SYMPTOMS AND SATISFACTION

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Thesis
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ABSTRACT

IAQ/IEQ problems are found in many high rise or big buildings. Due to the energy crisis, those buildings were designed to save energy, e.g. allow more natural light to come in, limit outdoor air flow into the building, etc. The aftermath is likely to be sick building syndrome and reduction of occupants' satisfaction. The building in this study is an office building located in central Bangkok, Thailand that has had a quite high rate of occupant complaints about IAQ/IEQ.

The purpose of this research was to study the prevalence of symptoms and levels of satisfaction of the occupants that were related to IAQ/IEQ on 6 floors (7^{th} - 12^{th} floors) of the 25 floor building. The measured IAQ/IEQ parameters were: respirable particulates, TVOCs, formaldehyde, ozone, carbon dioxide, temperature, relative humidity, light intensity, and noise. The data on occupants' demographics, history of health, symptoms, and levels of satisfaction were also collected from 286 subjects using a self-administered questionnaire via the company's intranet webpage. The IAQ/IEQ parameters and related symptoms and satisfaction levels were analyzed to identify any relationships.

The results revealed that the prevalence rate of IAQ/IEQ related complaints was 10.8% (31 out of 286). Among the 31 complaints, 90% of them came from people who worked in an area where the ventilation rate was lower than ASHRAE's recommendation. Furthermore, it was found that the ventilation rate significantly correlated with overall symptoms ($p < 0.05$); the IAQ/IEQ related symptoms, i.e. cold/flu, vomiting, and shortness of breath were correlated with levels of satisfaction of ventilation as well ($p < 0.01$). Thus, we may conclude that the ventilation rate is a key indicator of the occupants' symptoms and levels of satisfaction.

KEY WORDS: INDOOR AIR QUALITY / INDOOR ENVIRONMENT QUALITY / OCCUPANTS' SYMPTOMS / OCCUPANTS' SATISFACTION.

136 pages

การศึกษาความสัมพันธ์ระหว่างคุณภาพอากาศและสภาพแวดล้อม กับอาการและความพึงพอใจของคนทำงานในอาคารสูง

THE RELATIONSHIP BETWEEN INDOOR AIR QUALITY AND INDOOR ENVIRONMENT QUALITY WITH OCCUPANTS' SYMPTOMS AND SATISFACTION

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บทคัดย่อ

อาคารขนาดใหญ่หรืออาคารสูงส่วนใหญ่มักพบปัญหาคุณภาพอากาศและสิ่งแวดล้อมภายในอาคาร ทั้งนี้เนื่องจากวิกฤติพลังงานทำให้อาคารเหล่านั้นถูกออกแบบมาเพื่อประหยัดพลังงาน เช่น การให้แสงจากธรรมชาติเข้าสู่อาคารมากขึ้น จำกัดอัตราการไหลเข้าของอากาศจากภายนอก ซึ่งผลที่อาจตามมาคือผู้ที่อาศัยหรือทำงานมีอาการเจ็บป่วยหรือไม่พึงพอใจกับสภาพแวดล้อมภายในอาคาร อาคารที่ศึกษาเป็นอาคารสำนักงานตั้งอยู่ใจกลางของกรุงเทพมหานคร ซึ่งมีอัตราการร้องเรียนของผู้ที่อาศัยในอาคารค่อนข้างสูง

การศึกษานี้ได้ดำเนินการใน 6 ชั้นคือ ชั้นที่ 7 ถึงชั้นที่ 12 ของอาคารสูง 25 ชั้น เพื่อศึกษาความชุกของอาการที่อาจเนื่องมาจากคุณภาพอากาศและสภาพแวดล้อม และความพึงพอใจต่อคุณภาพอากาศและสภาพแวดล้อมของพนักงานที่ทำงานภายในอาคาร โดยตรวจวัดดัชนีบ่งชี้คุณภาพอากาศและสภาพแวดล้อม ครอบคลุม ฝุ่น สารระเหยอินทรีย์รวม ฟอร์มัลดีไฮด์ โอโซน คาร์บอนไดออกไซด์ อุณหภูมิ ความชื้น แสง และเสียง รวมทั้งเก็บข้อมูลเกี่ยวกับบุคคลที่ทำงานในอาคาร 286 คน ได้แก่ ข้อมูลส่วนบุคคล ประวัติสุขภาพ อาการ และความพึงพอใจ โดยใช้แบบสอบถามผ่านทางเว็บไซต์ของบริษัท และวิเคราะห์ข้อมูลทางสถิติเพื่อหาความสัมพันธ์ของปัจจัยเหล่านี้

ผลการศึกษาพบว่าอัตราความชุกของอาการและการร้องเรียนที่เกี่ยวข้องกับคุณภาพอากาศและสภาพแวดล้อม 10.8% (จำนวนผู้ร้องเรียน 31 คนจาก 286 คน) ในจำนวนนี้พบว่า 90% เป็นผู้ที่ปฏิบัติงานในพื้นที่ที่มีอัตราการระบายอากาศต่ำกว่าข้อแนะนำของ ASHRAE นอกจากนี้ยังพบว่าอัตราการระบายอากาศมีความสัมพันธ์ทางสถิติกับอาการโดยรวมอย่างมีนัยสำคัญ ($p < 0.05$) ในขณะที่อาการที่เกี่ยวข้องกับคุณภาพอากาศและสภาพแวดล้อมเช่น อาการหวัด อาการคลื่นไส้ และอาการหายใจลำบากมีความสัมพันธ์ทางสถิติกับความพึงพอใจของการระบายอากาศอย่างมีนัยสำคัญ ($p < 0.01$) ดังนั้นจึงอาจสรุปได้ด้วยว่าอัตราการระบายอากาศเป็นดัชนีชี้วัดที่สำคัญของอาการและความพึงพอใจของผู้ที่อาศัยในอาคาร

136 หน้า

CONTENTS

		Page
ACKNOWLEDGEMENTS		iii
ABSTRACT		iv
LIST OF TABLES		ix
LIST OF FIGURES		xi
LIST OF ABBREVIATIONS		xii
CHAPTER I	**INTRODUCTION**	
	Background and rationale	1
	Objectives	2
	Research hypotheses	2
	Scope and limitation of the study	3
	Variables	3
	Expected outcomes and benefits	3
	Conceptual framework	4
	Glossary of terms and definitions	4
CHAPTER II	**LITERATURE REVIEW**	
	Indoor Air Quality and Indoor Environment Quality	6
	Factors affecting Indoor Air Quality	7
	Classification of indoor air contaminants and their health effect	16
	Standards for airborne concentration of Indoor Air Quality contaminants	30
	Measurement of indoor air contaminants	31
	Measurement of air intake rate	34
	Symptoms related to Indoor Air Quality problem	37
	Recommendation intake rate	38
	Literature cited	40

CONTENTS (cont.)

	Page
CHAPTER III MATERIALS AND METHODS	
Study design	45
Studied Population	45
Sample size	46
Materials and Instrument	46
Equipment calibration	46
Measurement and data collection	49
Data Analysis	51
Statistical and analysis	51
CHAPTER IV RESULTS	
Studied floor characteristics	53
The HVAC systems for the studied floor	57
General characteristics of buildings' occupant	58
The prevalence of occupants' symptoms related to IAQ/IEQ	62
IAQ/IEQ measurement in the office building	66
The correlation between IAQ/IEQ and occupants' symptoms	73
The correlation between occupants' symptoms and occupants' satisfactions	76
CHAPTER V DISCUSSION	
The prevalence of occupants' symptoms related to IAQ/IEQ and IAQ/IEQ measurement in the office building	78
The correlation between IAQ/IEQ and occupants' symptoms	79
The correlation between occupants' symptoms and occupants' satisfactions	79

CONTENTS (cont.)

Page

CHAPTER VI CONCLUSION AND RECOMMENDATIONS

Conclusion 81

Recommendation 82

Recommendation for further study 83

REFFERENCES 84

APPENDICES

APPENDIX A: Floor / zone layout 91

APPENDIX B: Documentary proof of ethical clearance 94

APPENDIX C: Information sheet 95

APPENDIX D: Instrument picture 101

APPENDIX E: Questionnaire form and web survey 105

APPENDIX F: The survey of environment building form 116

APPENDIX G: The survey of office building contaminant sources form 119

APPENDIX H: The measurement layout 120

APPENDIX I: The calculation of ventilation rate 123

APPENDIX J: The ventilation measurement layout 124

APPENDIX K: The lighting measurement result 127

BIOGRAPHY 136

LIST OF TABLES

Table		Page
2-1	Chemical emission from building materials and furnishing	7
2-2	Sources of indoor air contaminants	8
2-3	Principle sign and symptom at various concentrations of Carboxyhaemoglobin	19
2-4	Effects of exposure to Nitrogen dioxide with various concentrations	20
2-5	Mean tobacco-related contaminant levels in public access buildings.	22
2-6	Total concentrations of VOCs (mg/m^3) reported from nonindustrial at mospheric environments	24
2-7	Common indoor particulate	25
2-8	Typical biologics that contribute to indoor air pollution	28
2-9	The recommended standard of airborne concentration of OAW	30
2-10	Frequency of reported systems in NIOSH building investigation	38
2-11	Outdoor air requirements for ventilation recommended by ASHRAE	38
2-12	Contaminant concentration standard in general building by ASHRAE, WHO-IAQ research 1984, OSHA-proposed rule 1994 and EPA	39
2-13	Acceptable concentration	39
2-14	Occupants' symptoms related to IAQ/IEQ	42

LIST OF TABLES (cont.)

Table		Page
4-1	The type and number of the rooms/areas	55
4-2	Sources of IAQ/IEQ in the building	56
4-3	Demographics data of buildings' occupants	59
4-4	Number of occupants with health history sensitive to IAQ on each floor	60
4-5	Satisfaction level for IAQ/IEQ parameters	61
4-6	The prevalence of IAQ/IEQ related symptoms by floor	63
4-7	The prevalence of IAQ/IEQ related symptoms by zone	64
4-8	IAQ/IEQ measurement on the 7th to12th floor	67
4-9	The ventilation rate measurement on the 7th to 12th floor	68
4-10	The correlation between IAQ/IEQ and occupants' symptoms	74
4-11	The correlation between occupants' symptoms and occupants' satisfactions	77

LIST OF FIGURES

Figures		Page
2-1	HVAC system	10
2-2	Acceptable range of operative temperature and humidify for person clothed in typical summer and winter clothing, at light activities, mainly sedentary (≤ 1.2 met)	15
2-3	The outdoor air flow rate required as a function of physical activity and steady state room concentration of CO_2	41
2-4	Outdoor ventilation requirements as a function of peak indoor CO_2 concentration	43
4-1	Floor plan	55

LIST OF ABBREVIATIONS

Abbreviation or symbol	Term
ACGIH	American Conference of Governmental Industrial Hygienists
ACR	Air Change Rate
AHU	Air Handling Unit
BMS	Building management system
^oC	degree Celsius
cm^2	square centimeter
ETS	Environmental tobacco smoke
Fig.	Figure
Fl.	Floor
g	gram
IS	Internal Standard
IAQ	Indoor Air Quality
IEQ	Indoor Environment Quality
L	liter
LOD	The limit of detection/detection limit
mg	milligram
µg	microgram
m^3	cubic meter
min	minute
ml	milliliter
NIOSH	The National Institute for Occupational Safety and Health
OSHA	The Occupational Safety and Health Administration

LIST OF ABBREVIATIONS (cont.)

Abbreviation or symbol	**Term**
PAU	Primary air handling unit
SD	standard deviation
TLVs	Threshold Limit Values
v	volume

CHAPTER I
INTRODUCTION

1.1 Background and rationale

Energy crisis has been an issue in all countries over the world since 1970; many energy conservation measures have been employed such alternative energy resource, reducing the use of energy, etc. In order to save tight building, minimize fresh air entering the building is one way employed in many cold region countries such as Europe and North America. Such measure could cause health impact to occupants, so call IAQ problem. The same problem and solution seems to occur in Tropical region where cooling system has been popular.

Nowadays IAQ has become a significant occupational health and safety issue among office staff, especially in a big city like Bangkok. Due to the cost and limitation of the land, many business offices rent area in high-rise buildings located in center of the city. Tight building seems to have more benefit than only energy saving, i.e. protection occupants from outdoor air pollutants such as traffic which is the major sources of pollutants and comes with people and the development. A few studies were conducted concerning IAQ in some office buildings (1), the results showed that none of pollutant levels exceeded the IAQ recommended standard, however, it was suggested that the ventilation rates should be increased due to high level of CO_2, and some related IAQ symptoms, such as headache and eye irritation, etc. were found.

The building under the study was renovated in 2006. The ventilation rate in the building was one of the factors that the owner of the building concerned. Thus, fresh air has been introduced into the building at the minimum acceptable rate. However, according to nurse services center of a company during the year 2006-2008, there were symptoms records with top three i.e. cold of 38%, headache of 20% and eye irritation of 14%. Based on the WHO's criteria that 20% of the occupants may be experiencing health or comfort problems, the building may be counted as "sick". Thus, it is interesting to investigate if there is any other factor affecting to human's health similar to that of the IAQ. As the environmental conditions such as noise, light, temperature and humidity has been suspected to cause such effects to people as well (2) thus, the study would include the environmental factors so called indoor environmental quality (IEQ) into the studied factors.

The studied building has twenty-five floors built on Sukhumvit 16, next to Queen Sirikit Exhibition and Conference Center, near the sky-train and sub-way stations, and opposite to the Benjakiti Park and Lake. Moreover, a tobacco factory was established on the West of the building, about 800 meters away. Hence, the purpose of this study was to investigate the relationship between IAQ/IEQ and occupants' symptoms and satisfactions. The results could be beneficial to not only this building's occupants but also the others in the same area and in big city like Bangkok too.

1.2 Objectives

1.2.1 The general objective:

To study the relationship between IAQ/IEQ with occupants' symptoms and satisfactions in the office building.

1.2.2 The specific objectives:

1.2.2.1 To study the prevalence of occupants' symptoms related to IAQ/IEQ.

1.2.2.2 To assess IAQ/IEQ in the office building.

1.2.2.3 To study the relationship between IAQ/IEQ with occupants' symptoms.

1.2.2.4 To study the relationship between IAQ/IEQ with occupants' satisfactions

1.3 Research hypotheses

1.3.1 IAQ/IEQ have relationship with occupants' symptoms.

1.3.2 IAQ/IEQ have relationship with occupants' satisfactions.

1.4 Scope and limitation of the study

The scope of this study involves IAQ/IEQ in office building and occupants' symptoms and satisfactions. The studied office buildings are located in Bangkok. Number of occupants in the building was approximately 500. The studiesd parameters were include respirable particulate, total volatile organic compounds, formaldehyde, ozone, carbon dioxide, ventilation rate, temperature, relative humidity, illumination, and noise. Web survey was used in order to collect occupants' symptoms and satisfactions rating to IAQ/IEQ

1.5 Variables

1.5.1 Independent variables

1.5.1.1 Respirable particulate, total volatile organic compounds, formaldehyde, ozone, carbon dioxide, ventilation rate, temperature, relative humidity, illumination, and sound.

1.5.2 Dependent variables

1.5.2.1 IAQ/IEQ related symptoms

1.5.2.2 IAQ/IEQ related satisfactions

1.6 Expected outcomes and benefits

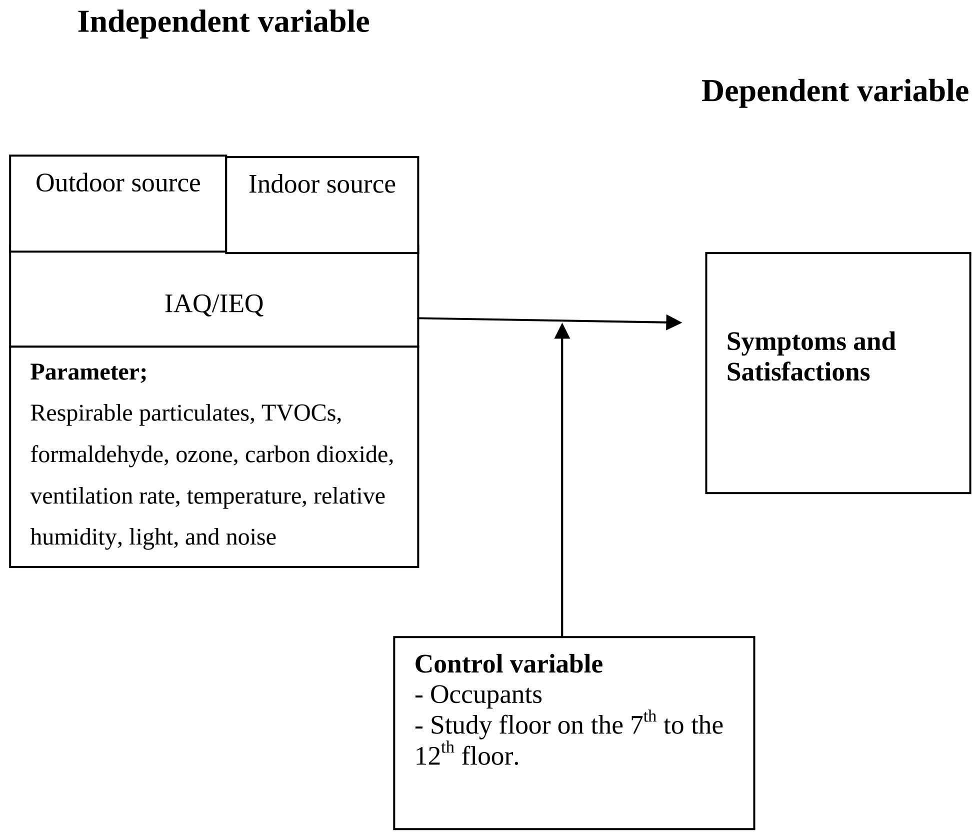
1.6.1 To realize the prevalence of occupants' symptoms in relation to IAQ/IEQ in the office building

1.6.2 To identify IAQ/IEQ in office building with reference to international standard.

1.6.3 To recognize the relationship between IAQ/IEQ with occupants' symptoms.

1.6.4 To recognize the relationship between IAQ/IEQ with occupants' satisfactions.

1.7 Conceptual framework



1.8 Glossary of terms and definitions

1.8.1 Indoor Air Quality: IAQ means the state of chemical contaminant and HVAC factors which affect indoor air quality such as carbon dioxide, relative humidity, total volatile organic compounds, formaldehyde, ozone, respirable particulate matters, and ventilation rate.

Indoor Environmental Quality: IEQ means the state of physical factor which affect indoor environmental quality such as temperature, humidity, illumination, and noise.

1.8.2 Ventilation rate refers to the amount of air supplied per person per init of time; this is expressed as the number of cubic feet per minute per person (cfmpp).

1.8.3 Occupants mean the people working on the 7th to 12th floor of the studied building.

1.8.4 Occupants' Symptoms or overall symptoms means the occupants' report the state of symptoms related to IAQ/IEQ through web survey during monitoring indoor air environment such as headache, eye irritation, nose irritation, cold symptoms, dizziness or faintness, exhaust, drowsy, dry mouth, vomit, throat irritation, shortness of breath or chest pains, dry skin or itchy skin or itchy skin rash, back pain, fever etc.

1.8.5 Occupants' Satisfactions means the occupants' report the state of IAQ/IEQ satisfactions by scoring on the most responsive satisfaction level while monitoring indoor air environment; which is classified into 5 levels i.e. slightly, low, medium, high, and very high. The assessment is conducted through a web survey on the satisfaction of IAQ/IEQ

1.8.6 Zone means the area defined by Air Handling Unit. There are 3 zones on each floor of the office building. (see Appendix A)

1.8.7 Building Management System (BMS) is a computerT-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems the program for building facility control. Its core function is to manage the environment within the building.

CHAPTER II
LITERATURE REVIEW

2.1 Indoor Air Quality and Indoor Environment Quality

Energy demands of the 1970s and early 1980s spawned financing schemes for capital retrofits, which forced engineers to become increasingly accountable for predicted energy saving (3). Energy conservation was an important factor considered in the design and construction of new buildings and the retrofitting of existing building (4, 5). The buildings were sealed, tighter envelops to minimize infiltration of outdoor air. The heating and cooling system was reduced in the intake of outside air. Ventilation was designed to mechanical system with re-circulated air. The cracks and leaks were patched and insulation was added to walls and ceiling. Furthermore, new technology has introduced new building materials which turned to be sources of pollutant in indoor environment. They emitted large numbers of chemical into the air such as formaldehyde or solvent from carpeting (5, 6). The chemical emissions from building materials and furnishings were shown in table 2.1 (6). Nowadays, a lot of people spend most of their time indoors, thus they expose to such chemicals may complain about irritation, discomfort and other flu-like symptoms. Because the HVAC, designed to use much less outdoor air make up, can not take the effective control of the contaminants generated in building. Hence the pollutants can accumulate to the level that can affect the occupants (7).

The symptoms experienced by occupants in such buildings are associated with the respiratory tract or express as headaches, dizziness, nausea, lethargy and fatigues. Other symptoms are revealed in areas where the body is directly exposed such as dry or itchy and eye irritation (4). When causal factors can not be identified or no specific etiological, the health complaints is described as sick building syndrome (SBS) (7). The building is defined as sick if 20% or more of the building’s occupants exhibit such symptoms and the complaints persist for more than two weeks.

Particularly, if the symptoms disappear when the occupants leave the building for the weekend (4,5).

Table 2.1 Chemical emissions from building materials and furnishings (6)

Material	Typical Pollutants Emitted
Adhesives	Alcohols, Amines, Benzene, Decane, Dimethylbenzene, Ethylbenzene, Formaldehyde, Limonene, Nonane, Octane Terpene, Toluene, Xylenes, Other VOC
Caulking compounds	Alcohols, Alkanes, Amines, Benzene, Diethylbenzene, Ethylbenzene, Formaldehyde, n-Propylbenzene, Methylethylketone, Xylenes, Other VOC
Carpeting	n-Dodecane, 2-Ethylhexanol, Formadehyde, 4 Methylethylbenzene, 4-Phenylcyclohexene, n Propylbenzene, n-Undecane, Other VOC
Ceiling tiles	Formaldehyde
Chipboard/particle board	Amines, 3-Carene, Ethylbenzene, Formaldehyde, n-Hexane, Limonene, n-Pentanol, n-Propanol, 2-Propanone n-Propylbenzene, Terpene
Floor and wall coverings	Amines, Alkane, C3-benzene, C4-benzene, n-Butanone Diethylbenznene, Ethylacetate, Formaldehyde, Isopropylbenzene, Methyl stylene, Xylenes, Other VOC
Paints	C4-benzene, 2-Ethoxyethanol, 2-Ethoxyethylacetate Isopropylbenzene, Limonene, n-Propylbenzene, Toluene
Stains and varnishes	Amines, Benzene, Decane, Dodecane, Formaldehyde, n-Heptane
Upholstery	Formaldehyde
Vinyl-coated wallpaper	Amines, n-Decane, Formaldehyde, 1,2,4-Trimethylbenzene, Xylene

2.2 Factors Affecting Indoor Air Quality

The factors involved in the development of IAQ are as follows:

1) Sources of indoor air contaminants
2) The heating, ventilating, and air conditioning (HVAC) system
3) Building occupants
4) Physical factors

2.2.1 Source of indoor air contaminants

Source of indoor air contaminants are divided into 2 groups i.e. 1) Exterior sources are those originated outside the building and transported into the building by infiltration through building envelope, open windows and doors and the ventilation intake. Sources of such contaminants are pollens, dust, fungal spores, industrial pollutants, and vehicle exhaust gas, 2) Interior sources are the typical sources of contaminants generated in indoor environment including components such as furnishings, appliances, office equipments and human activity. Contaminants source and the examples are shown in table 2.2.

Table 2.2 Sources of indoor air contaminants (8).

Sources of contaminants	Typical
Exterior source	
• Contaminated outdoor air	Pollen, dust, fungal spores, industrial pollutants, general vehicle exhaust
• Emission from nearby sources	Exhaust from vehicles on nearby roads or in parking lots, or garages
• Emission from nearby sources	Unsanitary debris near the outdoor air intake, re-entrained exhaust from the building itself or from neighboring buildings
• Soil gas	Radon, pesticides
• Moisture or standing water promoting excess microbial growth	Rooftops after rainfall, crawlspace
Interior Source	
• HVAC system	Dust or dirt in ductwork or other components, microbiological growth in drip pans, humidifiers, ductwork, coils, improper use of biocides, sealants, and/or cleaning compound, refrigerant leakage
• Non HVAC system	Emission from office equipment e.g. VOC, ozone, elevator motors and other mechanical, emission from shops, labs, cleaning process

Table 2.2 Sources of indoor air contaminants (Cont.).

Sources of contaminants	Typical
Human activity	
• Personal activities	Smoking, cooking, body odor, cosmetic odors
• Housekeeping activities	Cleaning materials and procedures, use of deodorizers and fragrances, airborne dust or dirt e.g. circulated by sweeping and vacuuming
• Maintenance activities	Microorganisms in mist from improperly maintained cooling towers, VOC from use of paint, caulk, adhesives, and other products, pesticides from pest control activities
Building Components and Furnishings	
• Locations that produce or collect dust or fiber	Texture surface e.g. carpeting, curtains, and other textiles, open shelving, old or deteriorated furnishings, material contain damaged asbestos
• Unsanitary conditions and water damage	Microbiological growth on or in soiled or water damaged furnishings, microbiological growth in areas of surface condensation, standing water from clogged of poorly designed drains, dry traps that allow the passage of sewer gas
Other sources	
• Accidental events	Spills of water or other liquids, microbiological growth due to flooding or to leaks from roofs, piping
• Special use areas and mixed use buildings	Smoking lounges, laboratories, print shops, art rooms, beauty salons, food preparation areas
• Redecorating/Remodeling/Repair activities	Emission from new furnishings, dust and fiber from new demolition, odors and volatile organic and inorganic compounds from paint, caulk, adhesives, microbiological released from demolition or remodeling activities

2.2.2 The heating, ventilating and air conditioning (HVAC) system

HVAC system could be both source and solution of the IAQ problems. HVAC is the air handling system designed primarily for temperature, humidity odor and air quality control. Air temperature is controlled by heating or cooling the air, while air humidity and the water vapor content of the air, is controlled by humidifying or dehumidifying the air. Air quality is controlled by filtration, the removal of undesirable contaminants using filters or other devices, or by ventilations, the introduction of outside air into the space, which dilutes the concentration of contaminants and odor. (9, 10)

The main components of a HVAC system illustrates in figure 2.1(5). The outdoor air is brought in through the outdoor air supply dampers and transported to the mixing plenum for mixing with re-circulated air from the occupied spaces. The mixed air is passed a pre-filter to filter out large dust, bird feathers, leaves and flies, and an efficient filter to control small particles. Exiting the fan outlet, positive pressure, being pushed toward the coils. These coils heat or cool the air by removing or adding heat to the air. Heating coils may use steam, hot water, or electrical heater. Cooling coils usually use halocarbon refrigerants or chilled water as the cooling media. Leaving the coils, the air passes through a humidifier or dehumidifier for maintains relative humidity to about 40-60%. Conditioned air is delivered to occupied areas by the supply diffuser and is returned to the systems by the return grillers. (5,9,10)

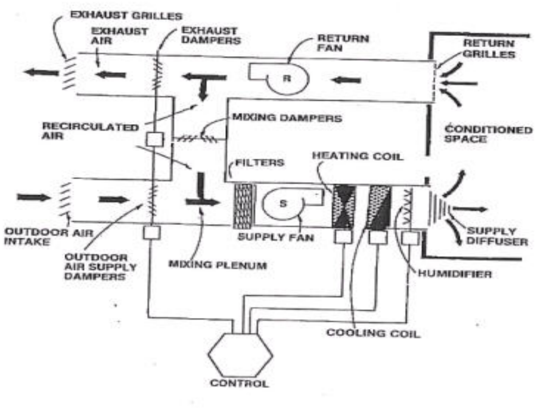


Figure 2.1 The heating, ventilating and air conditioning (HVAC) system. (1)

The HVAC system may contribute to IAQ complaints because it can serve as a pathway for contaminants to move from a source of generation to other building spaces and for outdoor contaminants to enter the building (7). The system's effectiveness affects productivity, performance and most importantly, health. Thus well designed HVAC system is the mainstay of healthy building. Oppositely, the malfunction of HVAC system, which arises from improper designed or maintained, is cited as a major IAQ source. A variety problems concerning HVAC system have been linked to poor IAQ and occupants complaints, e.g,

1) Inadequate air intake rate for the effective control of bioeffluent and other contaminants generated in building. This problem has been associated with such factors as (4,7,8,9)

- The provision of out door for ventilation purpose was not designed into the system
- The design of outdoor air capacity is inadequate for building needs.
- Increase in building occupant beyond initial design.
- Malfunction of system inlet dampers.
- System operating which minimize the provision of outdoor air for purpose of energy conservation and minimizing operating cost.
- Reduced air flows due to poor maintenance of filter, fans, and other HVAC system components.

2) Migration of contaminants from one building zone or space to another, cross-contamination. Airflow patterns in buildings result from the combined action of mechanical ventilation systems, human activity, and natural forces. Pressure imbalances created by these forces move contaminants from areas of relatively higher pressure to areas of relatively lower pressure through any available openings. Cross contamination often results as a consequence of pressure imbalances between building zones served by different air handling units. Pressure imbalances can occur in a single air handling unit of room supply and exhausts are not properly balanced. (7,8)

3) Re-entry of building exhausts. Contaminants may re-enter the building from exhaust vent because of the poor design and location of both exhausts and outdoor air intakes and by infiltration due to pressure imbalance in the building. (5,7,8)

4) Entrainment of contaminants generated outdoors as a result of the improper location of air intakes such as nearby cooling towers or at street level near high traffic areas. (7, 8, 11)

5) Generation of man-made mineral fibers (MMMF) from the disintegration of sound liners in air handling unit (AHUs) (5, 7)

6) Microorganisms and organic dust contamination in the HVAC equipments. The microorganisms may proliferate in poor maintenance of condensate drip pans, humidifier, air filters, cooling towers and air handler insulation. (4, 5, 7, 8)

7) Inadequate dust control. The poor operation and maintenance of HVAC systems may contribute to occupant complaints. In many case, dust control is limited to low efficiency dust filters which are designed to protect mechanical equipment only. Dirty system filters due to poor maintenance may decrease an efficiency of filtration. (7, 8, 10)

8) Inadequate control of temperature, relative humidity and air velocity are brought to a problem of thermal comfort.(7)

2.2.3 Building occupants

The health and comfort complaints reported to be associated with IAQ are due to a variety of factors which may have direct or indirect effect. The direct effect is associated with personal characteristics including gender, age, status, and a variety of lifestyle factors such as smoking, alcohol consumption, use of contact lenses, etc. (7) The building occupants may have different tolerance to the environment, most people in most circumstances are not affected but susceptible individuals may be. Thus susceptible occupants may have increased risk for experiencing or reporting SBS type complaints. For example, people with heart disease may be more affected by exposure at lower levels of carbon monoxide than healthy individuals. Children exposed to environmental tobacco smoke have been shown to be at higher risk of respiratory illness.(8) the groups that may be particularly susceptible to effects of indoor air contaminants include allergic or asthmatic individuals, people with respiratory disease, people whose immune systems are suppressed due to chemotherapy, radiation therapy, disease, or other causes and contact lens wearers, Raw, G.J. and A. Grey (12) have proposed that gender differences in symptom prevalence are due to the fact that males tent to under-report symptoms.

The indirect effect may be risk factors for SBS symptoms such as psychosocial phenomenon. A number of psychosocial factors have been reported to be significantly associated with building or work-related symptoms. These have included job category, dissatisfaction with superior or colleagues, quantity of work, job stress, general job dissatisfaction, occupant density, et. (7)

In the study of Burge, P.S.,et.al. (13), managers and professional/technical staff reported fewer symptoms than clerical staff. Reasons of these differences were mainly due to the enhanced accommodation of the manager/professionals in the building the greater degree of control over their job, and their ability to have changers made in the operation of building HVAC systems.

In the Dutch Office Building Study of Zwers, T. et all (14), the number of individuals in a work space was significantly associated with higher prevalence rates of oronasal, nervous system, temperature, air quality and dry air complaints. And the U.K. studies of Hawkins and Wang (15), individuals who perceived their office spaces to be crowed had significantly higher building symptom scores.

In addition to atopic histry, Skov, P. et al (16) have reported a relationship between the prevalence rate of general symptoms and respondent reports of migraine headache.

2.2.4 Other environmental factor (4, 6, 7)

2.2.4.1 Temperature. Thermal comfort can have an impact on the perception of IAQ. A number of variables interact to determine whether people are comfortable with the temperature of the indoor air. The activity level, age, and physiology of each person affect the thermal comfort requirements of that individual. The American Society of Heating, Refrigeration, and Air conditioning Engineers (ASHRAE) Standard 55-1981 recommend a range of 20 to 26^{o}C (68 to 79 ^{o}F) at 50% relative humidity that are comfortable for most people engaged in largely sedentary activities(17). Figure 2-2 demonstrates an acceptable range of operative temperature and humidity of persons wearing typical summer and winter clothing. The overlapping zones, 23 to 24 ^{o}C (73 to 75 ^{o}F), is the range that people in summer dress would tend to approach slightly cool while those in winter clothing would be near the slightly warm sensation. Temperatures above this range may increase the initial outgassing of VOC from materials (4).

In the study of Wyon, D. (18), the effects of moderate heat stress on typewriting performance was found at temperature above 24 ^{o}C. It reduced alertness of occupants.

Jaakkola et al. (19) suggested that sick building symptoms may reflect general satisfaction with building temperature.

Tavee wetchapreut and others (20), studied in thermal comfort and indoor air quality in Thailand. This study has shown optimum temperature at 24 ^{o}C (76 ^{o}F) and a range of 23 to 26 ^{o}C (73 to 79 ^{o}F) for 80% thermal acceptability of occupant.

2.2.4.2 Humidity. Humidity may have variety or relationships relative to health, comfort, and perceived satisfaction or dissatisfaction with air quality. Humidity significantly affects thermal comfort. (8, 7) Raising relative humidity reduces the ability to lose heat through perspiration and evaporation, so that the effect similarly raising the temperature. Low humidity has also been reported to have direct effects on mucous membranes and human skin (7). However, these are no agreement on an ideal range of relative humidity (RH). Currently the U.S. Environmental Protection Agency (EPA) suggests a range of 45 to 50% relative humidity. ASHRAE recommends that relative humidity should be kept below 60%. (4) Values that exceed 70% RH are often associated with microbial growth (8,21). Relative humidity below 20% has been reported to cause eye irritation (22), and several clinical reports have suggested that relative humidity above 30% is needed to prevent drying of mucous membranes and the maintenance of adequate mucous transport and ciliary's activity (14).

2.2.4.3 Artificial lighting. Lighting conditions may affect personal comfort in several ways. If lighting is poor, it may cause eyestrain and fatigue. Factors associated with poor illumination include inadequate lighting, excessive lighting, both direct and reflected glare, inadequate contrast, and dark shadows that may cause eye irritation and headache, which are symptoms commonly associated with poor IAQ (4, 14).

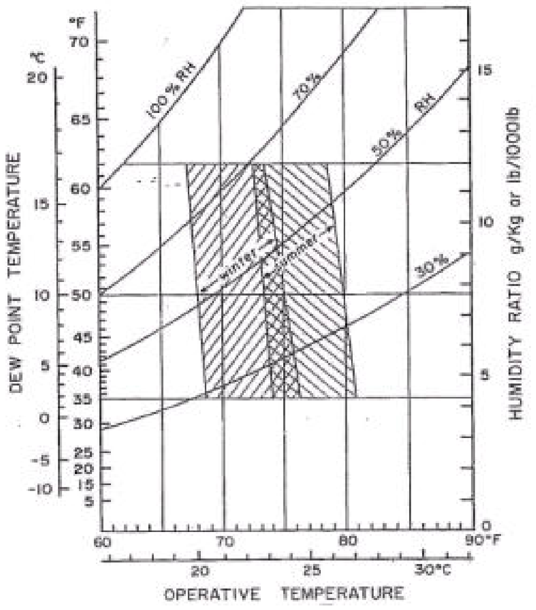


Figure 2.2 Acceptable range of operative temperature and humidity for person clothed in typical summer and winter clothing, at light activities, mainly sedentary (≤ 1.2 met). (17)

Rask, D.R. and other (23), studied in environmental stressors and system deficiencies identified in 51 problem office buildings indicate that lighting is major stressor in buildings. They described common symptoms alleged to be associated with poor luminosity to be headache, dizziness, drowsiness, fatigue, nausea, and eye irritation. Lighting described as harsh, dim, producing glare, etc. was reported to be a problem in 20 % of building investigation conducted.

Zweers, T. and others (24) studied in health and indoor climate complaints of 7043 office workers in 61 buildings in the Netherlands. They found that the average was lighting complaints 30% with a range of 8 to 53%. Lighting complaints in this study were significantly related to personal, workplace, and job characteristics including exposure to environmental tobacco smoke (ETS), allergy or respiratory symptoms, low job satisfaction, work with video-display terminals (VDTs), handling of carbonless copy paper, and lack of control over workplace temperature.

Hodgson, M.J. and others (25) reported on association between increased lighting intensity and complaints of chest tightness in a sick building investigation. However, no association between lighting intensity and SBS symptoms were observed in 4373 office worker of the U.K. sick building and the Danish Town Hall Studies. (4, 26)

2.2.4.4 Noise and Vibration. Noise has been described as an environmental stressor. Building with excessive noise could result in headache, dizziness, drowsiness, fatigue, and nausea of the occupants, which is similar to symptoms attributable to indoor air pollutants (4, 7). Not only the excessive level, but also the nature of the noise is important in causing these symptoms. Infrasound (0.1 to 20 Hz.) can cause dizziness and nausea, but usually only in level above 120 decibels (dB). It is probable that low frequency noise (20 to 100 Hz) commonly found in buildings containing industrial or HVAC equipment can also cause problems. Rask, D.R. and others (23) reported excessive noise or acoustical problems to be a concern in 16% of 51 building investigation conducted. These included air noise from diffusers, fans and nearby processes.

Vibration, a sound-related parameter, has also been reported to cause problem-building symptoms. In the study of Hodgson, M.J. and others, (6) concluded that vibration generated from a pump room was the causal contributor to symptoms reported by office in an adjacent office. (7)

2.3 Classification of Indoor Air Contaminants and their Health Effect

IAQ contaminants may be classified in several ways. The researcher identified as; 1) Combustion products, 2) Volatile Organic Compound (VOCs), 3) Aerosol, 4) Human Bioeffluents, 5) Bioaerosols, 6) Radon. This section will review such contaminants and their health effects.

2.3.1 Combustion products

The major categories of products resulting from combustion can be listed as inorganic gaseous pollutants, along with other organic pollutants and respirable particulate matter such as carbon monoxide (CO), nitrogen oxide (NO_x), silfur oxide (SOx), carbon dioxide (CO_2), polynuclear aromatic hydrocarbons (PAH), ammonia (NH3), smoke, etc. (15,16,27) The smoking of any tobacco product, cigarettes, cigars, and pipes, is a major source of combustion product that can contribute to indoor concentration levels of CO, NH_3 and CO_2. (30). Hence this section will discuss only the more frequently found contaminants:

1) Carbon monoxide (CO) is an odorless, tasteless and colorless gas that is slightly lighter than air. It is a product of the incomplete combustion of carbon containing materials. The largest indoor environmental sources of CO emission are incomplete combustion process including gas stoves and tobacco smoke. Motor vehicle exhaust is a primary source from outdoor. (5, 24) Thus the areas of hotel such as lobby and restaurants located near by parking areas or roads, especially in urbanized areas, may have high CO_2 concentration.

The health effect of CO caused by interference of oxygen (O_2) transportation to body tissues. Carbon monoxide competes with O_2 for binding sites on the heme portion of the hemoglobin (Hb) molecules in red blood cells to carboxyhemoglobin (COHb). The affinity of Hb for CO is about 240 to 250 times that for O_2. the formation of COHb reduces the oxygen-carrying capacity of blood and increases the O_2 affinity of the remaining hemoglobin binding sites, thus interfering with the release of O_2 at the tissue level. The resulting impairment of O_2 delivery causes tissue hypoxia and interferes with cellular respiration. Hypoxia leads to deficient function in sensitive organs and tissue like the brain, heart, the inner wall of blood vessels and platelets. (24, 25,26).

The appearance of symptoms depends on the concentration of CO in the air, the exposure time, the degree of exertion and individual susceptibility, COHb level of 3% to 5% may adversely affect the vigilance ability of a person. Hand to eye coordination can slow down at a COHb level of 6% to 10%. After 15 hours of exposure to 15 ppm of CO or 1 hour of exposure to 60 ppm of CO, the COHb level can increase to 2.5%. The relation between varboxyhaemoglobin concentrations and the main signs and symptoms is shown in table 2.3

The U.S.EPA has concluded that the following groups may be particularly sensitive to exposure of CO including angina patients, individuals with other types of cardiovascular disease, persons with chronic obstructive pulmonary disease, anemic individuals, fetuses, and pregnant women. (24, 25)

National Primary Ambient-Air Quality Standards (NAAQS) for Outdoor Air as set by the U.S. EPA. has enacted the standards for CO, that it does not exceed

35 ppm averaged over a 1-hour period and 9 ppm averaged over an 8-hour period (27). The Canadian exposure guidelines for residential indoor air quality has developed acceptable exposure for CO, do not exceed 25 ppm averaged over a 1-hour period and 11 ppm averaged over an 8-hour period (29). The World Health Organization has published air quality guidelines for Europe, the concentration of CO do not exceed 85 ppm. The Germany established maximal arbeitslatz konzentrationen (MAK values), CO do not exceed 30 ppm. The American Conference of Government Industrial Hygienists (ACGIH) has enacted the Industrial workplace standard of CO, do not exceed 25 ppm over the time-weighted average (TWA), an 8-hour workday or and 40-hour workweek (30).

2) Nitrogen oxides (NO_x) are a mixture of gases that are composed of nitrogen and oxygen. (31) Several oxides of nitrogen such as nitric oxide (NO), nitrogen dioxide (NO_2), and nitrous oxide (N_2O) are produced from the reaction of atmospheric nitrogen and oxygen during high temperature combustion processes. (27) NO_x can be outdoor or indoor sources. Indoor NO_x sources include water heaters, ovens, stoves, and environmental tobacco smoke. Outdoor sources of NO_x are combustion associated processes such as motor vehicles. (31,32) The major NO_x present in indoor air are NO and NO_2, both are nonflammable and colorless to brown at room temperature. NO is a sharp sweet-smelling gas at room temperature. NO_2 has a pungent odor, highly corrosive, a strong oxidizing agent and is a liquid at room temperature, and becoming a reddish-between gas above 70^{o}F. (31, 33)

The health effect of low-level nitrogen oxides exposure is irritation in eyes, nose, throat, and lungs, leading to cough and shortness of breath, tiredness, and nausea. Breathing high level of nitrogen oxides can cause rapid burning, spasms, and swelling of tissues in the throat and upper respiratory tract, reduced oxygen-carrying capacity of blood to body tissues, a build-up of fluid in the lungs, and death. Skin or eye contact with high concentrations of nitrogen oxide gases

Tables 2.3 Principle sign and symptoms at various concentrations of carboxyhaemoglobin

Carboxyhaemoglobin Concentration (%)	Principle signs and symptoms
0.3 – 0.7	Physiologic norm for non smokers
2.5 – 3.0	Cardiac function decrements in impaired individual; blood flow alterations; and, alter extended exposure, changes in red blood cell concentration
4.0 – 6.0	Visual impairments, vigilance decrements, reduced maximal work capacity, norm for smokers
10.0 – 20.0	Slight headache, lassitude, breathlessness from exertion, dilation of blood cells in the skin, abnormal vision, potential damage to fetuses
30.0 – 40.0	Weak muscles, nausea, vomiting, dimness of vision, severe headaches, irritability, and impaired judgment
50.0 – 60.0	Fainting, convulsions, coma
60.0 – 70.0	Coma, depressed cardiac activity and respiration, sometimes fatal

or nitrogen dioxide liquid can causes serious burns. (31,34) The NO_2 health effects experienced at various exposure levels as shown in table 2.4. (32)

NAAQS for NO_x is an annual arithmetic mean value not exceed 0.053 ppm (27). The Canadian exposure guidelines for residential indoor quality has developed acceptable exposure for NO_2, do not exceed 0.25 ppm averaged over a 1-hour period and 0.05 ppm averaged for long-term exposure (12). ACGIH standards of NO_2 do not exceed 3 ppm averaged for the TWA (30). The WHO guideline for Europe of NO_2 concentration do not exceed 0.2 ppm averaged over a 1-hour period and 0.8 ppm averaged over 24 hour. The MAK values for NO_2, not exceed 5 ppm.

3) Carbon dioxide (CO_2) is the colorless, odorless gas with a faint acid taste. The gas is produced when carbonaceous substances burn in excess of air or oxygen. It is a product of fermentation processes and from the human metabolism and exhaled through the lung. CO_2 is found in the ambient environment at 325 to 350 ppm. Levels in the urban environment may be higher due to emission from gasoline and, more often, diesel fuel engine.

Table 2.4 Effects of exposure to nitrogen dioxide with various concentrations. (32)

Concentrations of NO_2 in air (ppm)	Exposure time	Principle signs and symptoms
300	---	Lethal
150	---	Death after 2 or 3 weeks by brochiolotis, fibrosis obliterans. Produced chronic lung disease
50	---	Bronchitis
10	---	Impairment of ability to detect odour
5	15 min	Impairment of normal transport of gases between the blood and lungs in healthy adults
2.5	2 hr	Increased airway resistance in healthy adults
1.0	15 min	Increased airway resistance in bronchitis patients

Carbon dioxide can become dangerous not as a toxic agent but as a secondary asphyxiant. When concentrations exceed 35,000 ppm, central breathing receptors are triggered and cause the sensation of shortness dysfunction due to simple displacement of oxygen. At a concentration of 100,000 ppm can produce unconciousness in an exposed person, who will die from oxygen deficiency unless he is relocated to a normal atmosphere or is given oxygen resuscitation. (30)

Exposure controls for carbon dioxide are generally limited to situations where exposure concentrations are expected to exceed 3 to 5%. CO_2 is not encountered at levels harmful to humans in the ambient environment The Canadian guidelines concentration of CO_2 do not exceed 3,500 ppm. ACGIH standard, the recommended exposure limits has developed by NIOSH and the MAK values for the CO_2 do not exceed 5,000 ppm. (5,7,30)

4) Tobacco smoke. The smoking of tobacco products in indoor environments represents a potentially significant environmental exposure and SBS symptom risk (7). Working or occupancy in an environmental where smoking is permitted can lead to high levels of exposure to environmental tobacco smoke (ETS). Exposure to ETS is referred to passive or involuntary smoking. ETS is made up of

exhaled mainstream smoke, sidestream smoke emitted from smoldering tobacco, contaminants emitting during the puffs and contaminants that diffuse through the cigarette paper and the mouth end of cigarettes between puffs. Emissions contain both particle phase and vapor phase contaminants. Sidestream smoke is the major component of ETS, contributing over half of the particulate matter and nearly all of the vapor phase. ETS, sidestream smoke and mainstream smoke are complex mixtures of over 4,000 compounds. These include more than 50 known or suspected human carcinogens, such as 4-aminobiphenyl, 2-napthylamine, benzene, nickel, and a variety of polycyclic aromatic hydrocarbons and N-nitrosamines. A number of irritants such as ammonia, nitrogen oxides, sulphur dioxide and various aldehydes, and cardiovascular toxicants, such as carbon monoxide and nicotine are also present. (35, 36)

Health effects of ETS include upper respiratory irritation, coughing, wheezing, sneezing, headache, and sinus problems. The severity of symptoms is related to the airborne concentration and the sensitivity of the individual. For allergic or asthmatic persons, the problem can be intense. People wearing contact lenses complain of burning and tearing eyes. (36)

A number of studies have reported concentrations of ETS in a variety of public-access buildings. Data from some of these studies are summarized in table 2.5, which reported for environments where smoking density was relatively high. (35, 37, 38, 39, 40, 41, 42)

Sterling and Mueller (1) measured CO, CO_2, respirable suspended particles (RSP) and nicotine in smoking, nonsmoking section and nonsmoking areas which re-circulated air from smoking designanted areas in office building. This study found the average concentration of CO, CO_2, RSP and nicotine were (3.6, 2.6, 1.8 ppm); (690, 560, 490 ppm); (70, 32, 6 $\mu g/m^3$) and (14,6, 2 $\mu g/m^3$) in the smoking, nonsmoking and nonsmoking which received re-circulatd air respectively. Significantly higher levels of CO, CO_2, and RSP levels in nonsmoking office areas as compared to those which received re-circulated air.

Table 2.5 Mean tobacco-related contaminant levels in public access buildings. (35, 37, 38, 39, 40, 41, 42)

Contaminant	Type of environment	Levels	Nonsmoking controls	Ref.
		ppm		
CO	15 restaurants	4	2.5	57
	Area (11,806 people)	9	3.0	58
	44 work rooms	2.8	2.0	59
		μg/m^3		
RSP/TSP	Bar and grill	589		60
	Bingo hall	1140		60
	Fast food restaurants	109		60
	44 work rooms	117		59
	Restaurant	200		62
	Cocktail lounge	400		61
	Restaurant	240		55
	Restaurant	144		55
		ppb		
NO_2	Restaurant	63		62
NO	Bar	21	50	62
	44 work rooms	84	62	59
Nicotine	Restaurant	5.2		62
	Cocktail lounge	10.3		62
	44 work rooms	1.1		59
		Ng/m^3		
Benzo-∞-pyrene	Area	9.9	0.69	58

2.3.2 Volatile Organic Compounds (VOCs)

Organic compounds that exist as a gas, or can easily off gas under normal room temperatures and relative humidity, are considered volatile. Organic compounds found in indoor air include very volatile organic compounds (VVOCs) with boiling points which range from less than 0^oC to 50-100 ^oC, volatile organic compounds (VOCs) with boiling points in the range of 50-100 to 240-260 ^oC, semi-volatile organic compounds (SVOCs) with boiling points in the range of 240-260 to 380-400 ^{o}C, and organic compounds which are solids and have boiling points in excess of 380 ^{o}C.

Hundreds of VOCs are found in the indoor air including aliphatic hydrocarbons, aromatic hydrocarbons, halogenated hydrocarbons and oxygenated hydrocarbons namely aldehydes, alcohols, ketones, esters, ethers, and acids. These are emitted by a variety of sources including photocopying materials, paints gasoline, people, refrigerants, personal hygiene and cosmetic products, building materials, molded plastic containers, disinfectants, cleaning products and environmental tobacco smoke. Some of these sources emit several VOCs. For formaldehyde, phenols, ammonia, aromatic hydrocarbons and toluene. (7, 43)

Symptoms and health effects attribute to VOCs include respiratory distress, sore throat, eye irritation, nausea, drowsiness, fatigue, headaches and general malaise. Hodgenson and Morey (44) reported complaints when the concentrations of TVOC in air were less than 400 $\mu g/m^3$, At 600 $\mu g/m^3$, more than 20% of occupants complained of URT irritation and/or headache. Mol have suggests sensory perception (e.g., smell) to VOC occurs at about 1000 $\mu g/m^3$.

The USEPA group conducted studies in which 26 male and 15 female subjects were exposed to a 25 mg/m^3 TVOC mixture and to putatively clean air. Though they were observed to have increased eye, nose, and throat irritation, greater odor intensity and unpleasantness, and reduced perception of air quality during exposure, there were no differences in sensory effects observed between males and females. Again they were observed no effect of the exposure on neurobehavioral performance.

Table 2.6 shows the total concentrations (TVOC) reported in these 12 studied to the measurements of gases and vapors in the indoor air environment. The concentrations in older houses (range 0.02-1.7 mg/m^3) seem to be about 1 of 10 that found in new houses, where the range of concentrations is from 0.5 mg/m^3 to 19 $mg/m^{3.}$

2.3.3 Aerosol

A suspension of solid or liquid particles in the air is called an aerosol. Aerosols include mist, smoke, dust, fibers, and bioaerosols such as viruses, bacteria, fungi, algae, and pollen. Despite, their difference in chemical composition or biological properties, this includes particles in the size range from about 0.001 to 10 µm that remain in air for long period of time. It also includes larger particles up to 100 µm, which settle out of calm air in a matter of minutes.

Table 2.6 Total concentrations of volatile organic compounds (mg/m^3) reported from nonindustrial atmospheric environments (7)

Environment	Uninhabited		Inhabited	
	New	Old	New	Old
Dwellings	0.48-18.7	0.24-0.52	12.9	0.02-1.7
				0.25
				1.05
Offices	-	-	-	0.09-1.51
				0.4-1.6
Schools	-	0.01	0.86	0.13-0.18
		0.05		0.14
				0.29-0.50
				0.22-0.31

Particle size is the most important physical parameter for characterizing the behavior of aerosols. Table 2.7 lists size ranges for commonly found particles. The size distribution of aerosols reflects the nature of the nearby aerosol sources and the process of growth, transport, and removal.

Particles found indoors, such as house dust and airborne aerosols, consist of a number of minerals, metals, textiles, paper, building materials, fibers from insulation, particles form various biological sources [e.g. skin, scales from people, animal allergens, growth of microorganisms, and pollen) and chemical substances (PAHs)]. The relative contributions of each of these sources depend on the activities and materials within the building.

Health effects include triggering asthma, coughing, wheezing, respiratory irritation, premature death and effects of the eyes.

EPA has recommended and annual ambient air quality standard of 0.075 mg/m^3 for total suspended particulate, and more recently, a limit of 0.05 mg/m^3 for particles less than 10 micrometers in diameter. (PM-10). ASHRAE has suggested these standards as an upper limit for indoor air concentrations.

Table 2.7 Common Indoor Particles

Particle	Diameter, µm
Skin flakes human	1-40
Visible dust and lint	>25
Dust mite	50
Mite allergen	5-10
Mold and pollen spores	2-200
Cat dander	1-3
Bacterial	0.05--.7
Viruses	<0.01-0.05
Amoeba	8-20
Mineral fibers	3-10
Asbestos	0.25-1
Resuspended dust	5-25
Tobacco smoke	0.1-0.8
Diesel soot	0.01-1
Outdoor fine particles (sulfates, metals)	0.1-2.5
Fresh combustion particles	<0.1
Metal furmes	<0.1
Ozone-and terpene-formed aerosols	<0.1

Hanssen, S.O. (44) studied 7 school buildings in Finland on the effect of ventilation rate of the reporting symptom of occupants. This study reveals that the ventilation rate have relation with the occurrence of general symptom and the respirable particulate level associated with the type of floor covering and building occupants. The study reported relatively high respirable particulate levels which appears to be affected by the presence of carpeting and building occupancy.

Injira N., Sunantha J. and Paitoon N. (45) studied the IAQ in grilled food tabletop cooking restaurant in department stores in Thailand and they found that the maximum concentration of CO, PM10 and NO_2 from electrical cooking stove were 3.99 ppm, 0.236 mg/m^3 and 0.174 ppm, respectively, from gas cooking stove were

4.54 ppm, 0.076 mg/m^3 and 0.734 ppm, respectively, and from charcoal cooking stove were 12.54 ppm, 0.467 mg/m^3 and 0.573 ppm, respectively. An electrical stove was considered to be the most suitable type of stove out of the three. The study found that ventilation rates, as number of air delivered to occupied volume in one hour, exceeded the Building Control Act requirement (by 7 times).

Turnel et. Al (21) search in 185 offices, it found that respirable particulate was 20 ± 17.6 µg/m^3 at non-smoking area, and respirable particulate was more than 2 times at smoking area was 46± 6.9 µg/m^3. Christopher Y. Chao, Kelvin K. Wong's research concentrations were 71.5 µm/m^3 for smoking home and 60.0 µg/m^3 for non-smoking home. The average PM10 concentration of smoking homes was 19% higher than the average PM10 concentration of non-smoking homes.

2.3.4 Human Bioeffluents

Contaminants generated by the human body, described as bioeffeluents, have historically been a major IAQ concern. This concern has been both of an odor and comfort nature. It has been suggested that occupant discomfort is associated with bioeffluent levels in the range of 600-1000 ppm CO_2 or higher. Because CO_2 is the bioeffluent produced on the greatest abundance and is easily measured, it has served as an indicator of bioeffluent levels and a crude indicator of ventilation adequacy. (26,46)

Carbon dioxide (CO_2) is produced by human metabolism and exhaled through the lungs. The amount of CO_2 produced is a function of food composition and the activity level of an individual. The amount of CO_2 normally exhaled by an adult with an activity level representative of an office worker is about 200 ml/min (0.0073 cfm) (47)

Carbon dioxide has been a surrogate for indoor air quality, as the concentrations of carbon dioxide rise, background levels of other contaminants also increase. As concentrations of carbon dioxide exceed 1000 ppm, complaints and symptoms related to other contaminants become significant. NIOSH suggests the following relationships:

600 ppm minimal air quality complaints

600-1000 ppm potential complaints, "less clearly interpreted"

1000 ppm suggests inadequate ventilation and complaints such as headaches, fatigue, URI.

ASHRAE Standard 62-2002 (29), which recommends a ventilation rate of 20 cfm (10 L/s)/ person for office buildings and 15 cfm (7.5 L/s)/person for schools and other buildings, would be equal to guideline CO_2 values of approximately 800 and 1000 ppm CO_2. Carbon dioxide at these levels or even several thousands of ppm higher is generally not considered to be toxic.

Carbon dioxide levels in the ambient (outdoor) air average approximately 355 ppm. Within a building, CO_2 metabolically produced and released in human respiration may cause CO_2 to vary from those in the ambient environment to levels in excess of 4500 ppm. Carbon dioxide levels in a building and by implication, bioeffluent levels, are dependent on occupant density and the outdoor ventilation rate.

Other bioeffluents reported for indoor air include acetone, acetaldehyde, acetic acid, alkyl alcohol, amyl alcohol, butyric acid, diehyl ketone, ethylacetate, ethyl alcohol, methyl alcohol, phenol and toluene.

Turiel, I. et al., (48) studied on the effect of reduced ventilation on IAQ in a San Francisco office building. The study result reveals that the number of occupants and the ventilation rate including office used the outdoor air mode and recirculation mode had the relationship with CO_2 level. It was shown that CO_2 level in a building depend on occupancy density and the outdoor ventilation rate.

2.3.5 Bioaerosols

Bioaerosols (also, biogenic particles, airborne organisms, microbes, microbiological agents, microbial agents, microorganisms, viable pathogenic aerosols) are particles of biological origins. They are a normal, albeit unseen, part of our everyday life. Indeed, life could not exist without them.

Bioaerosols include fungi, bacteria, viruses, algae, amoebae, pollen grains, and the dead particles they produce. They may also include plant parts, insect parts, and animal parts and wastes such as saliva urine, feces and dander.

Today it is known that biological agents contaminate the air we breath within residential and commercial buildings. Typical of bioaerosol and their source contributed to indoor air quality, shown in table 2.8.

There are three critical requirements for the growth of microorganisms in any environment: 1) appropriate humidity; 2) appropriate temperature; and 3) appropriate physical and nutritional substrata.

Exposure to airborne fungal spores, hyphal fragments, or metabolites can cause a variety to respiratory diseases. These range from allergic diseases including allergic rhinitis, asthma and hypersensitivity pneumonitis to infectious disease such as histoplamosis, balstomycosis and aspergillosis. In addition, acute toxicosis and cancer have been described to respiratory exposure to mycotoxins. A large body of literature supports an association between moisture indicators in home and symptoms of cough and wheezing.

Table 2.8 Typical biologics that contribute to indoor air pollution

Class	Airborne Biologic Agent or Product	Indoor Source
Algae	Whole organism Cellular components	Outdoor air, HVAC (rare)
Arthropods and insects	Whole organism Body parts (antigenic components) Feces (antigenic components)	House dust, furnishings, building materials, food
Bacteria	Whole organism Cellular components (spores, cell walls) Cellular metabolites (endotoxin)	Cooling towers, stagenant water reservories, floods Industrial processes
Fungi	Whold organisms Cellular components (spores, hyphae) Cellular metabolites	Damp surfaces, HVAC system, bird droppings, outdoor air
Plants	Plant stems and leaves (antigens) Plant components (pollens)	Outdoor air and indoor air
Protozoa	Whole organisms Cellular components (antigens)	Stagnant water reservoirs, Pets (rare)
Viruses	Whole organisms	Humans and pets (rare)

2.3.6 Radon

Radon-222 (Rn-222) is a noble gas decay product of radium-226 (Ra-226) which in turn is part of the decay chain of uranium-238 (U-238). Ra-222 has a half life of 3.8 days and is essentially inert to chemical reaction. Radon diffuses through rock and soil after it forms. In mines, it enters the air from the ore or is brought into the mine dissolved in water. In homes, the principal source is soil gas, which penetrates through cracks or sumps or around a concrete slab. Any substance containing uranium or radium is a source of Ra-222. Because uranium-238 is universally presented in the earth, radon is a ubiquitous indoor air pollutant, and it is also presented in outdoor air. Infrequently, building materials or water may also contribute significantly to indoor concentrations. Indoor concentrations are usually 5 to 10 times greater than outdoor concentrations.

Radon is an alpha emitter which decays with a half-life of 3.5 days to a short-lived series of progeny. Unlike radon, the progeny are solid, and form into small molecular clusters or attach to aerosols in the air after their formation. The inhaled particulate progeny may be deposited in the lung on the epithelium, by contrast, is largely exhaled, and some radon is absorbed through the lung. Radon itself is not responsible for the critical dose of radioactivity delivered to the lung cancer in miners, Bale (1980) and Harley (NRC 1999) recognized in the early 1950s that alpha emissions from radon progeny and not form radon itself were responsible for the critical dose of radiation delivered to the lung. Alpha decays of two radioisotopes in the decay chain, polonium-218 and polonium-214, deliver the energy to target cells in the respiratory epithelium that is considered to cause radon-associated lung cancer. Alpha particles, equivalent to a helium nucleus, are charged and have a high mass. Although their range of penetration into tissues is limited, they are highly effective at damaging the genetic material of cells. As reviewed in the report of the Biological Effects of Ionizing Radiation (BEIR) VI Committee, passage of even a single alpha particle through a cell can cause permanent genetic change.

2.4 Standards for airborne concentration of IAQ contaminants

The concentration of exposure to the air borne and the dose-response relationship were used for consideration on the health effect and the standard for these contaminants for the standard of IAQ contaminants. There is a number of guidelines or recommendations namely e.g. ASHRAE-62, EPA, etc. The standard has been suggested by the ACGIM TLV for an upper limit of the other contaminants. (27, 29, 30, 49)

Table 2.9 The recommended standard of airborne concentration.

Air Contaminant	Canadian	WHO/ Europe	NAAQS /EPA	NIOSH	OSHA	ACGIH	Singapore
Aerolein	0.02 ppm			0.1 ppm 0.25 ppm (15min)	0.1 ppm 0.3 ppm (15min)	0.1 ppm 0.3 ppm (15min)	-
Accetaldehyde	5.0 ppm			ALARA	100 ppm 150 ppm (15min)	100 ppm 150 ppm (15min)	-
Formaldehyde	0.1 ppm	0.081 ppm		0.016 ppm 0.1 ppm (15min)	0.75 ppm 2 ppm (15min)	0.3 ppm	0.1 ppm
Carbon dioxide	3500 ppm			5 000 ppm 3 0000 ppm (15min)	10000 ppm 30000 ppm (15min)	5000 ppm 9000 ppm (15min)	1000 ppm
Carbon monoxide	11 ppm (8h) 25 ppm (1h)	8.6 ppm (8h) 25 ppm (1h) 51 ppm (30min) 86 ppm (15min)	9 ppm (8h) 35 ppm (1h)	35 ppm (8h) 200 ppm (15min)	35 ppm (8h) 200 ppm (15min)	25 ppm (8h)	9 ppm
Nitrogen dioxide	0.05 ppm 0.25 ppm (1h)	0.08 ppm(24h) 0.2 ppm (1h)	0.053 ppm (1yr)		1ppm (15min)	3 ppm 5 ppm (15min)	-
Ozone	0.12 ppm (1h) No long-term level	0.08 ppm (8h) 0.1 ppm (1h)	0.12 ppm (1h) 0.085 ppm (8h)	0.1 ppm (15min)	0.1 ppm (8h) 0.3 ppm (15min)	0.05 ppm (8h) 0.2 ppm (15min)	0.05 ppm
Particulate<2.5 MMAD	40 μg/m^3 (8h) 100 μg/m^3 (1h)		50 g/m^3 (1yr)		5 mg/m^3 (8h) (respirable dust)	40 μg/m^3 (8h) (no asbestos<1% crystallin	150 μg/m^3

Table 2.9 The recommended standard of airborne concentration of OAW(Cont.).

Air Contaminant	Canadian	WHO/Europe	NAAQS /EPA	NIOSH	OSHA	ACGIH	Singapore
Sulphur dioxide	0.019 ppm 0.038 ppm (5min)			2 ppm (8h) 5 ppm (15min)	2 ppm (8h) 5 ppm (15min)	2 ppm (8h) 5 ppm (15min)	-
Radon	800Bq/ m^3						-

2.5 Measurement of Indoor air contaminants

2.5.1 Sampling Methods

It is essential that sampling and instrumental measuring techniques appropriately selected to the task. Sampling procedures should be sufficiently sensitive to measure the contaminant or contaminants in the range expected in the sampled environment. The use of sampling techniques/instruments which has a lower limit of detection (LOD) above the range can be expected for indoor environments is wasteful of both resources and time

In addition to the LOD, sampling methods should be selected on the basis of their specificity and accuracy. Procedures which have gained acceptability as a consequence of systematic evaluation by testing/evaluating organizations such as The National Institute of Occupational Safety and Health (NIOSH), the U.S. Environment Protection Agency (USEPA), and the American Society for Testing and Materials (ASTM), or similar agencies/bodies in other countries are in most cases more appropriate than those for which there is little knowledge of performance and limitation of usage. The use of reference methods or approved methods may give investigators a relative degree of confidence about the validity of a chosen method and its application.

In addition to performance characteristics, the selection of a contaminant measuring method will depend on resource availability. Despite significant limitations, less expensive methodologies are, in many cases, preferred to more costly ones.

2.5.2 Electronic Direct-Read Instruments

A variety of electronic direct-read instruments are available for measuring the concentrations of indoor air contaminants. Such instruments allow the operator to obtain real-time or quasi-real-time measurements of gas, vapor, or particulate matter concentrations. They are usually pump-driven devices which draw air into a chamber where contaminant concentrations are determined by chemical or physical sensors, employing such principles as electrochemistry, photometry, infrared analysis, and chemiluminescence. Specific contaminant concentrations can be read from the deflection of a matter needle on a concentration scale or a digital output. Portable electronic direct-read instruments are available and widely used for the measurement of CO_2, CO and respirable particles (RSP) in indoor environments. Portable direct-read instruments are also available for ozone (O_3), a contaminant associated with office copiers.

2.5.3 Quality Assurance/Calibration

Contaminant measurement, whether undertaken as in systematic, research studies or as one-time tests in problem-building investigations, are all require quality assurance in order to provide confidence in value measurement. The Calibration of instruments used in collecting air samples or making contaminant measurement is among the primary focus of quality assurance programs. Calibration is a process whereby measured values of air flow or contaminant levels are compared to a standard. The standards used can be primary or secondary with the latter traceable to the former. Sampling equipment should be calibrated in the anticipated range of field measurements. It is customary to calibrate field instruments both before and after sampling.

In addition to calibration, good quality assurance programs will also include the use of field blanks, media blanks, replicate samples, and split or spiked samples as appropriate. Replicate samples can be used to assess the precision of sampling and analytical methods. An appropriate number of field blanks should be employed so that extraction efficiency or potential media contamination can be assessed by laboratory personnel conducting sample analyses. Two field blanks for each of ten active samples are recommended as a general guide.

2.5.4 Procedures for Commonly Measured Chemical/Physical Contaminants

The concentrations of gas, vapor, or particulate-phase contaminants are often measured during problem-building investigations based on a hypothesis that a particular contaminant or contaminants are a problem or for screening purposes. These often include CO_2, CO, formaldehyde, total volatile organic compounds (TVOCs), and specific VOCs. Less commonly, particulate matter (TSP or RSP) levels are measured.

1) Carbon Dioxide

Because it is used as an indicator of ventilation adequacy, CO_2 is the most commonly measured contaminant in IAQ investigations. Such measurements are exclusively made by means of direct-read sampling devices. Portable battery-operated, real-time electronic direct-read instruments are widely used for CO_2 measurements in building investigations. The operation of these instruments is based on the principle of the differential absorption of infrared energy by different levels of CO_2. An internal pump draws air through the instrument allowing it to respond quickly to changes in CO_2 levels. These instruments may have one or two operating ranges: 0-2000 ppm and 0-5000 ppm. They are relatively easily calibrated from zero gases and CO_2 air standards. Carbon dioxide direct-read monitors have the advantage of high accuracy (±10% or less) and the ability to make numerous measurements in time and space with considerable ease. These devices can easily be connected to record so that CO_2 level changes with time can be easily determined.

2) Respirable particulate

A variety of sampling and instrumental methods are available for measuring particulate matter in the respirable size range. These include gravimetric methods in which particulates are collected on filters with concentrations reported in micrograms or milligrams per cubic meter. Respirable particles can also be measured by real-time or near real-time instruments using optical techniques. These include instruments that measure particle concentration in the aerodynamic size range of 0.1-10 μm by forward light scattering. Respirable particle levels are often measured using piezoelectric resonance. In piezolelectric devices, nonrespirable particles are removed by an impactor or cyclone. The difference in oscillating frequency between sensing and reference crystals is monitored and displayed as concentration in milligrams per cubic meter and calculate to the concentration of respirable particulate, C (mg/m^3) in the air volume sampled, C can be determined from the equation 2.1.

Where:

$$C = \frac{(W2-W1) - (B2-B1)}{V} \times 10^3, \ mg/m^3 \qquad \text{Equation 2.1}$$

C = Concentration of respirable particulate (mg/m^3)

W1 = tare weight of filter before sampling (mg)

W2 = post-sampling weight of sample-containing filter (mg)

B1 = mean tare weight of blank filter (mg)

B2 = mean post sampling weight of blank filter (mg)

V = volume as sampled at the norminal flowrate (i.e. 1.7 L/min or 2.2 L/min)

2.6 Measurement of Air Intake Rate (6, 50)

Outdoor air intake rates can be determined directly by the use of air flow instruments (assuming that infiltration air inflows are low). In many cases, it may neither be feasible nor desirable to conduct such measurements. Instead, outdoor air flows may be determined directly using a variety of techniques. These include measurements of CO_2, conduction enthalpy balanced and using tracer gases. These techniques can be used to determine the effectiveness of the ventilation system in removing indoor air contaminants.

2.6.1 Direct Techniques

The air intake rate can be directly measurement of the flow rate of intake at the intake grille. The percentage of outdoor air intake can be determined from the equation 2.2

$$\text{Outdoor Air Intake (\%)} = \frac{V_{oa} \ x \ A_{oa}}{V_{ahu} \ x \ A_{ahu}} \ X \ 100 \quad \Lambda \ \text{Equation 2.2}$$

Where:

V_{oa} = average outdoor air velocity flow in to the AHU

A_{oa} = the cross-sectional are through which outdoor air moves (ft^2)

V_{ahu}= the average mixed air velocity flow from the AHU to supply the area/rooms in the building

A_{ahu}= the cross-sectional area of the open face of air handling equipment

The percentage of outdoor air intake can be converted to the air intake rate by means of the equation 2.3

$$\text{Air Intake Rate(cfm/person)} = \frac{\text{\%OutdoorAirintakexTotalSuppliedair flow}}{N \ x \ 100} \quad \Lambda \ \text{Equation 2.3}$$

Where:

Total supplied air flow is the flow that provided to a room or zone, as determined from actual measurements (cubic feet per minute).

N is the average occupant in the room, as determined by counting the amount of occupants every hour (person) during the IAQ monitoring.

Air Change Rate can be determined from the equation 2.4

$$N = \frac{Q\ (cfm/min) \times 60}{Vol\ (cfm)} \quad or \quad \frac{Q(cms/sec) \times 3600}{Vol\ (cms)} \qquad \text{Equation 2.4}$$

Where;

N = air change per hour

Q = volume flow rate

Vol = volume

This equation where Q calculate from equation 2.5

Volume flow rate (Q) can be determined from the equation 2.5

$$Q = AV \qquad \text{Equation 2.5}$$

Where:

Q = volume flow rate (cfm or cms)

A = area (ft^2 or m^2)

V = air flow velocity (fpm or mps)

2.6.2 CO_2 Techniques

Outdoor air flow rates can be determined from measurements of CO_2 in return, supply and outdoor air. The percentage of outdoor air can be determined from the equation 2.6

$$Outdoor\ air\ (\%) = \frac{Cs - Cr}{Co - Cr} \times 100 \qquad \text{Equation 2.6}$$

Where:

Cs = ppm CO_2 in supply or mixed air in the AHU

Cr = ppm CO_2 in return air

Co = ppm CO_2 in outdoor air

The percentage of outdoor air can be converted to an outdoor air flow rate by means of the equation 2.7

$$\text{Outdoor air flow rate (L/s)} = \frac{\text{\%Outdoor air x Total air flow (L/s)}}{100} \quad \Lambda \text{ Equation 2.7}$$

The value used for the total air flow can be one that provided to a room or zone, the capacity of the AHU, or the total air flow of the HVAC system as determined from actual measurements.

2.6.3 Thermal Balance

The percentage of outdoor air can also be determined from temperature measurements of airstreams representing outdoor, return and mixed air (supply before it is heated or cooled). Access to the return/outdoor air mixing box (for the purpose of temperature measurements) is essential. This can be difficult or unlikely in some systems. A large number of temperature measurements of the mixed airstreams are recommended.

The percentage of outside air can be calculated from the equation 2.8

$$\text{Outdoor air (\%)} = \frac{Tr - Tm}{Tr - To} \times 100 \quad \Lambda \text{ Equation 2.8}$$

Where:

Tr = temperature of return air

Tm = temperature of mixed air

To = temperature of outdoor air

The percentage of outdoor air can be converted to a volumetric outdoor air flow rate by means of the equation 2.8

The major disadvantage of the thermal balance method is that it only assesses the amount of outdoor air introduced into the HVAC system and ignores infiltration. This is not true for CO_2 methods.

2.7 Symptoms Related to IAQ and IEQ problem

Sick building syndrome (SBS) is used to describe a diffuse spectrum of symptoms in which no specific ethiological factor can be identified. A working panel of the World Health Organization (WHO) initially attempted to define this phenomenon in the early 1980s. Sick building syndrome was defined on the basis of a group of frequently reported symptoms or complaints including 1) sensory irritation in eyes, nose and throat; 2) neurotoxic or general health problems; 3) skin irritation; 4) non-specific hypersensitivity reactions; and 5) odor and taste sensations. Sensory irritation was described as pain, a feeling of dryness, smarting, stinging irritation, hoarseness or voice problems; neurotoxic/general health problems as headache, sluggishness, mental fatigue, reduced memory, reduced capacity to concentrate, dizziness, intoxication, nausea and vomiting, and tiredness; skin irritation as pain, reddening, smarting, or itching sensations, or dry skin: non-specific hypersensitivity reactions as running nose or eyes, asthma-like symptoms among nonasthmatics, or sounds from the respiratory system; odor and taste sensations as changed sensitivity of olfactory or gustatory sense or unpleasant olfactory or gustatory perceptions.

In attempt to define and describe SBS, the WHO panel indicated that 1) mucous membrane irritation of the eyes, nose, and throat should be one of the most frequent symptom expressions; 2) other symptoms involving the lower respiratory airways and internal organs should be infrequent; 3) no evident causality should be identified in relation to occupant sensitivity or to excessive exposures: 4) symptoms should appear frequently in one building or part of it; and 5) a majority of occupants should report symptoms.

Field investigations are typically conducted as a consequence of occupant/building management requests. They have considerably varied methodologies employed, the training and capabilities of those conducting the investigation, and success in identifying and mitigating building-related health problems. In many NIOSH investigations reported symptoms were diverse and not specific enough to identify causal agents easily. These have included headache; eye, nose, throat and skin irritation; fatigue; respiratory problems such as sinus congestion, sneezing, cough and shortness of breath; and less frequently, nausea and dizziness, as shown in table 2.10.

Symptom prevalence as a percentage of investigated building (>50%), occupants reported symptoms of eye irritation, dry throat, headache, fatigue and sinus congestion. These symptoms were described, for the most part, both mucous membrane irritation and neurotoxic effects.

Table 2.10 Frequency of reported symptoms in NIOSH building investigations.

Symptom	% of Buildings
Eye irritation	81
Dry throat	71
Headache	67
Fatigue	53
Sinus congestion	51
Skin irritation	38
Shortness of breath	33
Cough	24
Dizziness	22
Nausea	15

2.8 Recommended air intake rate

Ventilation system is used to prevent and control the indoor air environment to sustain an acceptable air level rate for according to the ASHARAE. This suggestion also applies to the outdoor air requirement for ventilation in a variety of indoor spaces. The ASHARAE standard 62-2002 (29) was shown in table 2.11.

Table 2.11 Outdoor air requirements for ventilation recommended by ASHRAE. (29)

Application	Estimated Maximum Occupancy P/1000 ft^2 or 100 m^2	Outdoor Air Requirements			
		Cfm/ person	L/s* person	Cfm/ ft^2	L/s* m^2
Offices					
Office space	7	20	10		
Reception areas	60	15	8		
Telecommunication centers and data entry areas	60	20	10		
Conference rooms	50	20	10		

Table 2.12 Contaminant concentration standard in general building by ASHRAE, WHO – Indoor Air Quality Research 1984, OSHA-Proposed rule 1994 and EPA

Chemical	Concentration acceptance	Significant concentration
CO_2	350-1000 ppm	800-1000 ppm
TVOC	1-2 ppm	-
Formaldehyde	0.04-0.1 ppm	> 0.1 ppm
CO	1-5 ppm	> 5 ppm
NO_2	0.03-0.1 ppm	>0.05 ppm
Ozone	0.01-0.02 ppm	>0.05 ppm
Particulate matters	< 0.075 mg/m^3 (Total)	≥0.075 mg/m^3
	< 0.050 mg/m^3 (PM-10)	≥0.050 mg/m^3
Radon	0.5 µCi/L	4 µCi/L
Silica	0.01 fiber/cm^3 2 µg/ m^3	0.02 fiber/cm^3

Table 2.13 Acceptable Concentration

Contaminant	**Concentration**	**Time period**	**By**
CO	9 ppm	8 hr.	NAAQS
CO_2	1000 ppm	Continuous	ASHRAE
Formaldehyde (CH_2O)	0.1 ppm	Continuous	ASHRAE
NO_2	0.05 ppm	1 yr	NAAQS
O_3	0.05 ppm	Continuous	ASHRAE
Lead	1.5 ug/m^3	1 yr.	NAAQS
PM-10	150 ug/m^3	24 hr.	NAAQS
PM-10	0.05 mg/m^3	8 hr.	ASHRAE

2.9 Literature cited

Study conducted by Sasithorn Narongsak (1) on "the relationship between IAQ and sick building syndrome in Thailand" office buildings reported the prevalence of sick building syndrome in 305 individuals investigations. The prevalence of sick building syndrome reported in 63.61% of headache, 59.34% of nasal manifestation, 58.63% of supper respiratory tract infection, 58.03% of eye irritation, 48.85% of throat and lower respiratory tract symptoms and 42.30% of skin irritation. This study identified symptoms of eye irritations and nasal manifestation related with concentration of dust in air, symptoms of headache related with concentration of carbon dioxide in air and symptoms of upper respiratory track infection related with the amount of colony of bacteria in the air.

A study by Wantanee Punprasit and Witaya Yoosuk (51), studied on the indoor air quality of office building in Bangkok in comparison of the IAQ in different air conditioning type and building usage period. This study conducted in 4 office buildings. Two buildings installed central air-conditioning system; one is a new building with the usage period less than 1 year, and another is an old building with over 5-year usage period. And other two buildings installed split type air-conditioning; one is a new building whereas another is an old building. This study collected the data by interviewing occupants on their symptoms and sensation related to IAQ which were divided into 18 symptoms and measured the concentrations of ozone, CO_2, TVOC, formaldehyde, bioaerosol, temperature and relative humidity. The report revealed that the number of symptoms and sensation and prevalence of occupant symptom appeared in the old buildings than the new ones. Most areas of the 4 buildings have acceptable concentration of indoor air pollutant. Moreover, the CO_2 concentrations in some certain areas of the 2 old buildings and 1 new building are over the recommendation for acceptable ventilation of ASHRAE (1000 ppm.) Air-conditioning type is not related with CO_2 with CO_2 concentration and occupants' symptoms and sensation related to IAQ.

The ASHRAE study (52) on the requirement of ventilation of minimum physiological requirements for registration air based on CO_2 concentration by the experiment in chamber, found the outdoor air flow rate have linear relation with the

CO_2 concentration in the room. Figure 2.3 shows the outdoor air flow rate required as a function of physical activity and steady-state room concentration.

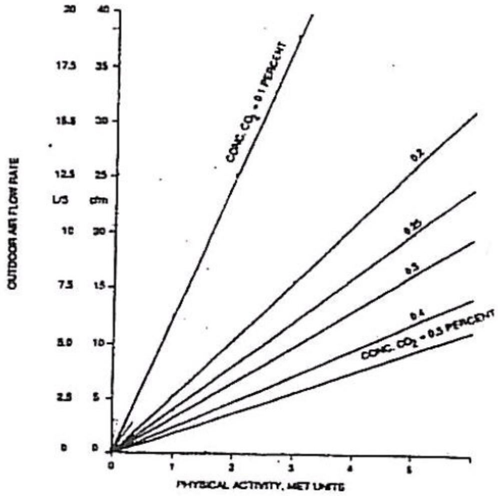


Figure 2.3 the outdoor air flow rate required as a function of physical activity and steady-state room concentration of CO_2 (52)

The study about four libraries in the University of Modena and Reggio Emilia (Northern Italy) to determine the presence of polluting agents such as total dusts, formaldehyde and other volatile organic compounds (VOCs) including benzene, toluene and xylenes and to assess the sense of well-being perceived by library users. Total dust values (40–350 $\mu g/m^3$) and total VOCs (203–749 $\mu g/m^3$) was observed. However, the perception of the different environmental parameters by the 130 library users that were interviewed identified the existence of some discomfort mainly caused by the feeling of poor ventilation. Moreover, 78.5% of the subjects stated they had at least one of the 16 investigated symptoms potentially related to a SBS (53)

The study on the Impact of Temperature and Humidity in the Perception of Indoor Air Quality in five building found a strong and significant impact of temperature and humidity on the perception of air quality (54)

The National Institute of Occupational Safety and Health (NIOSH) studied IAQ complaint causes in USA 1970, the total complaint report of 1,100. There was 50% from insufficient ventilation of indoor air in the building, 30% from contaminant in the building, 10% from out door air contaminant and 10% from other causes. The

American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) published ASHRAE 62-2002, Ventilation for acceptable indoor air quality, which specify minimum ventilation rates, outdoor air intake rate in cubic feet per minute (cfm) per person or liter per second (l/s) per person, for a variety of indoor spaces (29)

Environmental Protection Agency, 1991. The occupant's symptoms which related to IAQ and IEQ has shown in table 2.14

Table 2.14 Occupants' symptoms related to IAQ and IEQ, EPA

Symptom Patterns	Pollutant	Pollutant Sources
Thermal Discomfort	Indoor and outdoor temperature and humidity Radiant heat gain or loss.	HVAC equipment Stagnant and draft area
Headache, lethargy, nausea, drowsiness, dizziness	Carbon monoxide	Outdoor air intakes (combustion sources) Overall ventilation
Congestion; swelling, itching or irritation of eyes, nose, or throat; dry throat; may be accompanied by non-specific symptoms (e.g. headache, fatigue, nausea)	Formaldehyde Dust Gross microbial contamination	Sanitation problems, Water damage, Contaminated ventilation system. Outdoor allergen
Cough; shortness of breath; fever, chills and/or fatigue after return to the building	gross microbial contamination	Sanitation problems Water damage Contaminated HVAC system
Diagnosed infection	Legionnaire Histoplasmosis, Bacteria Fungi	Working environment
Suspected cluster of rare or serious health problems such as cancer, miscarriages		
OTHER STRESSORS Discomfort and/or health complaints that cannot be readily ascribed to air contaminants or thermal conditions	Environmental Ergonomic Psychosocial stressors	Environmental Human posture Job-related

A study by S.A Salisbury (55), studied the ventilation for controlling the IAQ in the office by the semi-experimental method, the outside air intake were adjusted to analyze the internal environment. The result found that the relationship between outside air ventilation rate and the peak of CO_2 in the exponential formal shown in figure 2.4., the outdoor air flow rates requirement can be determined by the graphic procedure (from figure 2.3), when the peak CO_2 at the time of measurements was taken. The outside air ventilation rate in this study was adjusted in the range of 5 to 40 cfm/person.

Snndell, J. et al.(56) studied in the Office Illness Project of Northern Sweden about the influence of the type of ventilation and outdoor air flow rate on the prevalence rate of SBS symptoms. This study was able to observe significant but weak associations between log outdoor flow rate and general symptoms (r = -0.46 for males; r = -0.39 for females), sensation of dryness (r = -0.30 for males; r = -0.39 for females), with mixed results for mucous membrane symptoms (r = -0.05 for males; r = -0.31 for females).

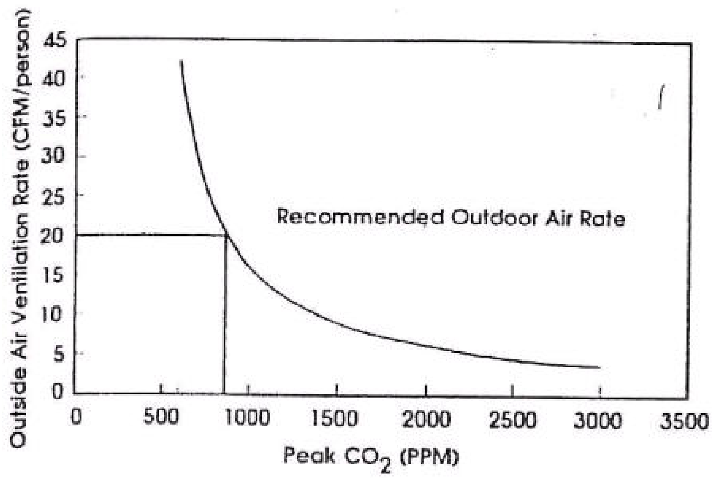


Figure 2.4 Outdoor ventilation requirements as a function of peak indoor CO_2 concentration. (4)

In order to investigate and control IAQ problems, there are several factors involved. However, under this section, the scope of this study objectively covers all major issues of indoor air quality, IAQ related factors, indoor contaminant classification and their health effect, IAQ contaminant standards, indoor air contaminant measurement, air intake rate measurement, IAQ related symptom problem and air intake rate recommendation.

Study conducted by Vorakamol Boonyayothin (57) on suitable air intake rate for hotels in Thailand shows that, for all room types, the air intake rate correlated with CO_2 levels, but not respirable particulate concentrations. Air intake rates also correlated with the occupants' complaints, except in bedrooms. The complaint symptoms concerning air intake rates were eye irritation, nose irritation, shortness of breath and chest pain. The room temperature has an impact on skin irritation and it is too cold only in the lobby area. The proposed air intake rates for the four types of rooms taken in this study were: lobbies 18 cfm/person, dinning rooms 15 cfm/person, conference rooms 23 cfm/person and bedrooms 15 cfm/person. Comparing ASHRAE recommended air intake rates for such types of the rooms, only the rates proposed for dinning rooms and bedrooms were lower than ASHRAE rates.

CHAPTER III
MATERIALS AND METHODS

3.1 Study design

This is a cross-sectional study, conducted in 25 floors building located on busy road in Bangkok. IAQ/IEQ were assessed using industrial hygiene instrument. Occupants' symptoms and satisfactions related to IAQ/IEQ were collected by the questionnaire using web survey. The relationship between IAQ/IEQ with occupant symptoms and satisfactions was evaluated.

3.2 Studied Population

An office building located on Ratchadapisek Road, the central business district in Bangkok was the studied building. It was constructed in early 2005. The occupied area of the building is approximately 1,644 square meters. Only the 7^{th} to 14^{th} floor are used as office spaces. Each floor accommodated approximately 150-200 occupants, giving total occupants about 1,600.

The studied floors were the 7^{th} to 12^{th} floors. The 7^{th} floor was studied only one zone, i.e. zone 2, because the rest was not opened for use. The number of the occupants was 489 persons who working in the office base. This study was reviewed and approved on May 2009; No. MU 2009-247 by the Ethics Committee on Human Rights Related to Human Experimentation, Mahidol University (Appendix B). Participation in this study was voluntary-based and the subjects were recruited upon completing a full written informed consent form (Appendix C).

3.3 Sample size

The sample size was calculated from $n = N/ (1+Ne^2)$ (58)

Where;

n = sample size

N = number of population

e = CI 95% (0.05)

n = 489/ (1+489x $(0.05)^2$)

n = 223 persons

So number of sample size was 223, according to the calculation. However, the questionnaire was distributed through the web survey to all occupants on the 7th to 12th floor and all the response will be counted.

3.4 Material and Instrument

3.4.1 IAQ/IEQ Equipment (see Appendix D)

(1) TSI IAQ Calc TM model Q-Trak Plus, serial number 8554-02071003

(2) MiniRAE 2000 Portable VOC Monitor Model PGM 7600

(3) Formaldehyde portable direct reading model no. Z-300, serial number 1165

(4) Ozone portable direct reading model no. Z-1200, serial number 1028

(5) Personal pump SKC AirCheck 52 Sampler Serial Number 818494-818498

(6) SKC UltraFlow® Serial Number 011809

(7) SKC Cyclone Serial number 225-69

(8) Field rotameter serial number 320-4A5

(9) Microbalance "SARTORIUS' electronic balance serial number 21508467

(10) Air velocity meter, Dick Smith Electronics, Model 8906 serial no. 9478554

(11) Lux meter, testo 545, serial no. 01054114/502

(12) Sound level meter, NL20, serial no. 00554898

3.4.2 Occupants' data collecting tool and the office buildings' data collecting tool

(1) Questionnaire (see Appendix E)

(2) The survey of environmental building form (see Appendix F)

(3) The survey of office building contaminant sources form (see Appendix G)

3.5 Equipment Calibration

3.5.1 Indoor air quality meter, TSI IAQ Calc^{TM}. Serial number 8554-02071003 was calibrated by Instrument Cal Lab Co., Ltd. on August 3, 2009 complying with the Gas Monitor Calibration Procedure number 203-001 under environment calibration condition as follows;

Ambient temperature (23±3) ^{o}C, relative humidity (50±20) %RH, and barometric pressure (760±5) mm.Hg. Calibration verification results as follows;

- Carbon dioxide sensor uncertainty in ppm was ±20.

- Temperature and relative humidity sensor uncertainty in Celsius and %RH was ±0.2 and ±3%RH respectively.

3.5.2 MiniRAE 2000 Portable VOC Monitor Model PGM 7600 was calibrated of using gases Iso-Butene in air. The reading was 91.0 ppm with uncertainty ±1.8 ppm absolute with SG-HC-08 method of analysis on May 23, 2009 by TIG PCL.

3.5.3 Formaldehyde monitors serial number 1165 was calibrated by Environmental Sensors Company on March 12, 2009. The compliance criterion overall system accuracy is better than ±10% at 0.54 ppm. This instrument has been calibrated using standards with accuracies traceable to the National Institute of Standards and Technology in an AIHA accredited laboratory.

3.5.4 Ozone monitor serial number 1028 was calibrated by Environmental Sensors Company on March 12, 2009. The compliance criterion overall system accuracy is better than ±10% at 3.50 ppm. This instrument has been calibrated using standards with accuracies traceable to the National Institute of Standards and Technology in an AIHA accredited laboratory.

3.5.5 Personal sampling pump SKC AirCheck 52 Sampler Serial Number 818494-818498 calibrated by using SKC Field Rotameters which is secondary standards, its calibrated by SKC UltraFlow® Serial Number 011809.

3.5.6 Microbalance “SARTORIUS’ electronic balance serial number 21508467 was calibrated by TISTR on June 25, 2009 in calibration range 1g~80/200 g, scale interval, readability:0.01/0.1 mg and ambient condition in temperature 26.3 ^oC to 26.1 ^oC, relative humidity 61.3% to 61.0%. Calibration point reading at 200g, correction +0.02 mg, and uncertainty ±0.18 mg.

3.5.7 Air velocity meter, RS232 Integral vane digital anemometer model 8906. The meter conforms to EN 50081-1/1992:EN 55022 standards with accuracy ± 3%FS of reading. Zeroing was perform before each use by turning on the air velocity meter without opening the sensor window, then reading the air velocity what would show at zero scale.

3.5.8 Lux meter Testo 545, serial no. 01054114/502 sensor was silicon photodiode and measurement range 0 to 100,000 lux. Accuracy to DIN 5032.

3.5.9 Sound level meter NL 20, serial no. 00554898 by electrical calibration with 1k-Hz since wave signal from built-in oscillator calibration using sound calibrator.

3.5.10 The questionnaire was adopted from the previous studied (57) as follows:

Part 1: Demographic data such as gender, age, education, race, area and zone where occupant worked, and time spending in the office building and others.

Part 2: Health history of the occupants such as diseases history, contact lens usage, and smoking habit.

Part 3: Occupants' symptoms that related to IAQ/IEQ such as headache, eye irritation, nose irritation, cold symptoms, dizziness, faintness, exhaustion, drowsy, dry mouth, vomit, throat irritation, shortness of breath or chest pain, dry skin or itchy skin or skin rash, back pain, fever etc. Apart from the mentioned symptoms, this also involves symptom patterns, serious and frequent symptoms etc.

The following symptom(s) were counted as not related IAQ/IEQ symptoms: no symptoms, symptoms is occurred once per month, symptoms frequency which more than 30 times per month, symptoms occurred all the time in the office, symptoms form non consistency, symptoms day occurred on Saturday or Sunday, the occupants who have health history of allergies, asthma, eye irritation and eyewear (contact lenses).

Part 4: Occupants' satisfactions concerning to dust, odor, air movement, temperature, light, and noise were qualitative classed, i.e. slightly=1, low=2, medium=3, high=4, and very high=5.

The questionnaire was developed and distributed by hand to 10 staff in the studied office to test validity. After the correction, it was distributed again via e-mail to 25 staff who was not the same as the first 10. Some technical problems using the on line survey were solved, and then it was sent to all staff.

3.5.11 The survey of environmental building form.

This survey was applied from Managing Indoor Air Quality (3) which included the building characteristics, building materials, HVAC system, smoke policy, and cleaning procedure.

3.5.12 The survey of office building contaminant sources form.

This survey was applied from Keeping Building Healthy (2) which identified pollutant sources in the building environment affecting IAQ&IEQ.

3.6 Measurement and Data Collection (See Appendix H)

The researcher had asked for the permission to collect data by means of IAQ/IEQ monitoring and questionnaire from the building management. All equipments were calibrated and check for measurable accuracy. The data collection methods are summarized as follows:

3.6.1 Carbon dioxide, relative humidity and temperature were measured continuously using indoor air quality meter. There are 3 zones divided in according to the AHU, on each floor the equipment was set at the central area of each zone without personal interruption. The collection processes take 3 hours for each zone. The measurement starts by turning on the power button and setting the data record every 5 seconds. The data was subsequently downloaded to a computer using the TSI program which shows the minimum, maximum and average value of each parameter.

3.6.2 Total volatile organic compounds (TVOCs) was measured using direct reading instrument, a VOC monitor (MiniRae 2000). Basically, this equipment monitors VOC using a Photo-Ionization Detection (PID) with a 9.8 eV gas discharge lamp. The measurements were taken in photo copy machine room and office working areas.

3.6.3 Formaldehyde (CH_2O) was measured using direct reading instrument, Formaldehyde meter model Z-300. The measurements were taken in office working areas. During the measurement, the meter was displaying an automated zeroing stage then stabilizing a value used as a background or a baseline for the measurement within 3 minutes, and the first value was the most precise measurement for recording which should last about 1 minute.

3.6.4 Ozone (O_3) was measured using direct reading instrument, Ozone meter model Z-1200. The measurements were taken in copy machine room and office working areas. During the measurement, the meter was displaying an automated zeroing stage then stabilizing a value used as a background or a baseline for the measurement within 3 minutes.

3.6.5 Respirable particulates were continuously measured using a personal sampling pump. The filter was prepared before conducting the measurement. Firstly, equilibrating the filters MEC 37 mm. in weighing area approximately 2 hours and recording the filter tare weigh, W 1 (mg). The microbalance was calibrated before weighing. Subsequently, assemble the filters in the filter cassettes (cyclone) and close them firmly with paraffin to avoid leakage. Next, placing a plug in each opening of the cyclone and assemble the sampler head. Check on the sampling head to ensure that filter holder and cyclone are aligned to prevent leakage. According to the sampling, calibrate each personal sampling pump to 1.7 L/min with a representative sampler in line. The sampling took 8 hours per sampler in each zone. Each filter was weighted. Recorded this post-sampling weight, W 2 (mg) and calculated applying the equation 1 (page 30).

3.6.6 Air velocity and cross-sectional area of diffusers were measured by air velocity meter and tape ruler. Dividing the inlet area by 1 square feet and measured each individual area. Next, the probe end was placed in perpendicular to the air flow, the sensor facing airstream. Allowing approximately 20 seconds for the sensor to warm up, waiting for the reading process to show stable value and then record the value.

3.6.7 The ventilation rate calculation. Firstly, calculated percentage of outdoor air from carbon dioxide concentration in equation 2.6; *Outdoor air (%) = [Cs – Cr]/ [Co –Cr] x 100*, then calculate volume flow rate (Q) in equation 2.5; *Q = AV*. Finally, calculate supply air per person (cfm/person).

3.6.8 Light was measured using lux meter. Photometer zeroing was adjusted, then placed the photo cell on the occupants' desks. The study was focused at assessing the impact on eyesight at particular spot. Then the figure of total specific spot values was calculated to one value representing zone. (27)

3.6.9 Noise was measured using a sound level meter. Weighting network A and slow response was used; microphone was set at hearing level of the occupants.

3.6.10 The questionnaire was distributed to all occupants through email. The objectives of the study were explained to all participants in the memo to the occupant requesting for their cooperation, the questionnaire completion was answered based on the occupants' willingness with in one-month timeline. The web survey program automatically closed within the above-mentioned period. During the launching of questionnaire, the researcher gave consultation for any inquiries from the occupants

3.7 Data Analysis

The data obtained from IAQ/IEQ measurement and questionnaire was collected and encode before processing through SPSS program.

3.8 Statistical and Analysis

The statistical significant level of 0.05 was selected. The data were analyzed using descriptive and analytical statistic as follows ;(59, 60)

3.8.1 Descriptive analysis

3.8.1.1 Frequency, percentage, mean and standard deviation were calculated for the demographic data and other characteristics of the occupants.

3.8.1.2 Mean and standard deviation were calculated for IAQ/IEQ data

3.8.1.3 Frequency, percentage and mean were calculated for the occupants' symptom and satisfaction.

3.8.2 Analytical Analysis

3.8.2.1 Pearson Chi-Square Correlation and Correlation coefficient was applied to test the association between

1) IAQ/IEQ and occupants' symptoms

2) IAQ/IEQ and occupants' satisfactions

CHAPTER IV
RESULTS

The results of this study were described in 7 main parts as the following:

4.1 Studied floor characteristic.
4.2 The HVAC systems for the studied floor.
4.3 General characteristics of buildings' occupant.
4.4 The prevalence of occupants' symptoms related to IAQ/IEQ
4.5 IAQ/IEQ measurement
4.6 The correlation between IAQ/IEQ and occupants' symptoms
4.7 The correlation between occupants' symptoms and occupants' satisfactions

4.1 Studied floor characteristic.

The data were collected on the 7^{th} to 12^{th} floor. Each zone has different type and number of rooms. The component of each studied floors were presented in Table 4.1. Every floors (7^{th} to 12^{th} floor) have similar lay out as shown in figure 4.1. There are 3 air handling units (AHU) see figure 4-1. AHU#1 supplies air to zone1; AHU#2 supplies air to zone 2 and AHU#3 supplies air to zone 3.

In general each floor has various functional rooms such as offices area; the management rooms, the meeting rooms, the utility room and the pantry room. The reception area has carpet sofa. There were synthetics curtain alongside front and back office. The senior management offices are alongside the wall and the staff working areas is outside the rooms, services rooms, i.e. copy machine room. Some floor has extra area/rooms, i.e., small outdoor green area where smoke allowed on the 7^{th} floor; first aid room on the 9^{th} floor and hub room on the 10^{th} floor where the temperature controlled at 23 ^{o}C of 24 hours

Building materials, interior furnishings, office equipments and cleaning solutions were surveyed, the results are:

The office ceiling was gypsum, interior wall made of gypsum and ceramic tile, and office floor lined with carpet, excepted on the 7^{th} floor was ceramic tile. For building structure, ceiling and floor were reinforced concrete, and room separated by curtain wall. The furniture in the office generally consist of synthetic curtain, carpet sofa etc. The office materials and furnish about 3 years old. During 3 years no redecorated recorded. The decoration on studied floors have done since September 2006.

The carpet and ceramic tile floor was cleaned once a week on Saturday while occupants' desk, meeting room and glasses door were cleaned daily. The cleaning tools included the mop, floor cleaning machine, cleaning liquid, air fresher, and a 70% alcohol solution for disinfection. In building area were mainly ceramic tile floor cleaning once a week on Saturday as well while daily cleaning only rest room and elevator.

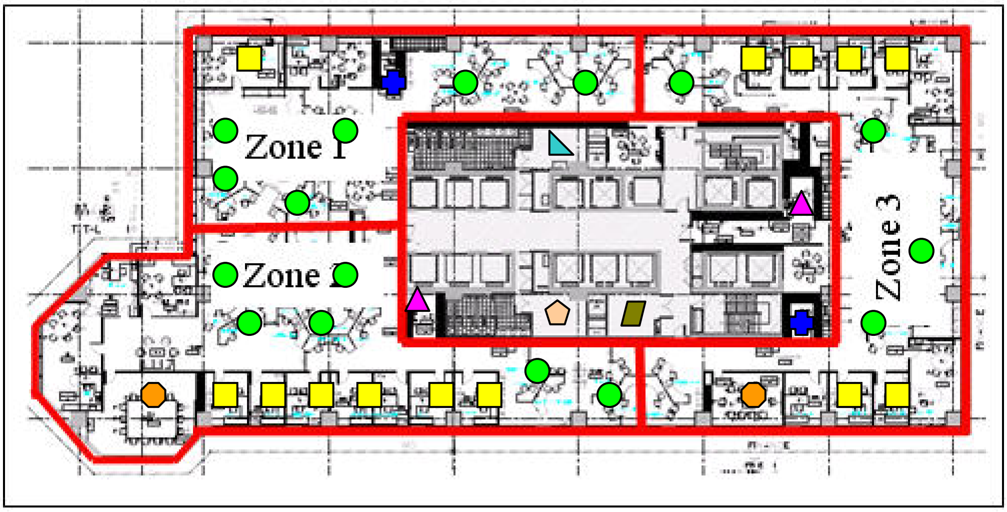
The IAQ contaminant sources were surveyed using the survey form (Appendix G). The contaminant sources were illustrated in table 4.2. IAQ contaminants maybe divided into 2 groups; firstly, external sources e.g. vehicle which generated respirable particulates, TVOCs, carbon dioxide, and sound. The tobacco factory where located closed to the building generated respirable particulates, TVOC, and formaldehyde. Secondly, internal sources e.g. photocopier which generated TVOC, and ozone, the occupants' generated respirable particulates, TVOCs, carbon dioxide and noise (see Table 4.2).

Table 4.1 The type and number of the rooms/areas

Floor	In general Functional area					Additional area			
	Management Room	Office area[a]	Meeting room/training room	Pantry[b]	Utility[c]	First aid room	Hub storage	Small outdoor green area	Reception area
7th	-	1[d]	4	1	1	-	-	1	1
8th	7	3	3	2	2	-	-	-	1
9th	13	3	4	2	2	1	-	-	2
10th	11	3	3	2	2	-	2	-	-
11th	11	3	4	2	2	-	-	-	-
12th	22	3	2	2	2	-	-	-	2

(a) Defined by AHU zone where is occupant working area (staff area) (b) consist of coffee services, microwave, refrigerator, and dish washing sink (c) equipped with photo copier machine, fax and paper digest machine (d) call centre

Figure 4-1: Floor plan



- Management Room
- Office area
- Meeting room/training room
- Pantry
- Utility
- AHU#1
- AHU#2
- AHU#3

Table 4.2 Sources of IAQ/IEQ in the building

	Source of IAQ/IEQ	IAQ/IEQ	Floor					
			7th	8th	9th	10th	11th	12th
External sources	ETS: Environment tobacco smoke	TVOCs/CH_2O/	✓	-	-	-	-	-
	Outdoor air (Vehicle, tobacco factory)	RP/TVOCs/CH_2O	✓	✓	✓	✓	✓	✓
	Sun light	Temp/Light	✓	✓	✓	✓	✓	✓
Internal source	Photocopier	TVOCs/O_3	✓	✓	✓	✓	✓	✓
	Cleaning liquid	TVOCs	✓	✓	✓	✓	✓	✓
	Microwave	TVOCs	✓	✓	✓	✓	✓	✓
	Pesticide material	TVOCs	✓	✓	✓	✓	✓	✓
	Disinfectant liquid	TVOCs	✓	✓	✓	✓	✓	✓
	Air fresher	CH_2O	✓	✓	✓	✓	✓	✓
	Document paper	CH_2O	✓	✓	✓	✓	✓	✓
	Interior furniture and office materials	RP/CH_2O	✓	✓	✓	✓	✓	✓
	Electrostatic air cleaning	O_3	-	-	-	-	✓	-
	Occupants	RP/TVOCs/CO_2/Noise	✓	✓	✓	✓	✓	✓
	Synthetic fabric	RP/TVOCs/CH_2O	✓	✓	✓	✓	✓	✓
	Fax	Noise	✓	✓	✓	✓	✓	✓
	Air compressor	Noise	✓	✓	✓	✓	✓	✓

4.2 The HVAC systems for the studied floor.

The HVAC system in the building is the central system. Fresh air is drawn into the building on the 25th floor at 2 sides of the building to replace air and dilute contaminants by 2 Primary Air Handling Unit(PAU) alternately. The capacity of the fans in the PAUs are 19,902 and 19,913 cfm. The system runs 05.45-18.30 hours in working days (Mon-Fri). The air travels through duct to supply the air handling unit (AHU) on each floor. The system is equipped with the filters removing particles and fibers from the air. The chiller is located at basement 3th floor which is operated during 06.00-16.30 hours. There are four chillers; three of 730 tons and one of 365 tons. In air handling units, on each floor, are operated during 07.30-18.30 hours. Outdoor air and return air recirculated through the mixing damper which control amount of recirculated and mixed at the mixing plenum. The mixed air is blown through the filter and across cooling coils into supply diffusers by supply fan; and finally delivered to occupied areas. Then air is removed from designated area through the return grilles and return air is drawn from the rooms and pushed into the evacuation and mixing ducts by a return fan to air handling unit or exhausted air to ground, basement 1st floor and basement 2nd floor. So in occupied zone, there are diffusers and return air grille. On each floor, there are exhaust grilles located in the pantry rooms which is conveyed in the duct to mix with exhaust air from rest room and exhaust at the basement 1st floor and basement 2nd floor.

According to HVAC maintenance procedure, the chiller is checked monthly and quarterly for AHU and PAUs. Equipment checking, filter and coil cleaning by high pressure water were mainly conducted. However, during the survey condensate drained from cooling coils in AHU#1 and AHU#2 was observed on the 7th to 12th floor.

4.3 General characteristics of buildings' occupant

The general characteristics of buildings' occupant were presented in table 4.3. Total number of occupants is approximately 500, subjects of the study was 286 (58.49%), 97 males and 189 females. The 11th floor has 74 (25.9%) occupants counted as one fourth of the subjects. The average age of the subjects was 34.22 (± 5.74 S.D). Work hour is 0800 – 1700 hours; the average time spending in the office building was 8.5 hours (±1.96 S.D.). The average time the subjects spend out off the office was 1.37 (±0.94 S.D.).

The occupants' health history which may sensitive to IAQ was illustrated in table 4.4. According to the questionnaire, the top three sickness of the occupants were cold 27.62%, dust allergies 24.83% and migraine 24.83%. Approximately one third was on the 11th floor. The numbers of subject wearing contact lenses were 84 persons; 22 persons(27.5%) are working on the 12th floor. Forty-six persons (16.08%) are smokers.

The occupants' satisfaction in the IAQ and IEQ was shown in table 4.5. The percentage of the highest satisfaction level for any parameter was less than 5%, while the slightly satisfaction level was less than 20%. The maximum percentage of the slightly satisfaction was for ventilation rate (11.89%). Over all satisfaction was at medium. The distribution of the satisfaction for all parameters is normal.

Table 4.3 Demographics data of buildings' occupants

Characteristics	N	Floor											
		7th		8th		9th		10th		11th		12th	
		n	%	n	%	n	%	n	%	N	%	n	%
No. of occupants	489	38	7.77	93	19.02	96	19.63	88	18.00	94	19.22	80	16.36
Avg. no. of visitor per day	70*	70*	100	8	11.43	10	14.29	12	17.14	30	42.86	10	14.29
No. of subjects	286	23	8	41	14.3	55	19.2	36	12.6	74	25.9	57	19.9
Male	97	5	21.7	19	46.3	24	43.6	14	38.9	28	33.8	10	17.5
Female	189	18	78.3	22	53.7	31	56.4	22	61.1	49	66.2	47	82.5
Age:													
21-30 yrs.	85	10	43.5	12	29.3	13	23.6	18	50	17	23	15	26.3
31-40 yrs.	166	12	52.2	28	68.3	30	54.5	17	47.2	50	67.6	29	50.9
41-50 yrs.	35	1	4.3	1	2.4	12	21.8	1	2.8	7	9.5	13	22.8
Mean ± S.D.	34.22 ± 5.74												
Time spending :													
In office													
1-4 hrs.	10	1	4.3	4	9.8	2	3.6	3	8.3	0	0	0	0
5-8 hrs.	123	4	17.4	20	48.8	34	61.8	15	41.7	30	40.5	20	35.1
9-10 hrs.	130	15	65.2	17	41.5	15	27.3	15	41.7	39	52.7	29	50.9
>10 hrs.	23	3	13	0	0	4	7.3	3	8.3	5	6.8	8	14
Mean ± S.D.	8.5 ± 1.96												
Off office													
0 hrs.	11	1	4.3	1	2.4	3	5.5	0	0	4	5.4	2	3.5
1-3 hrs.	259	21	91.3	35	85.4	48	87.3	30	83.3	70	94.6	55	96.5
4-6 hrs.	16	1	4.3	5	12.2	4	7.3	6	16.7	0	0	0	0
Mean ± S.D.	1.37 ±0.94												

* Number of visitors on 7th floor and total number of visitor were equally because of all visitors will registered on 7th floor.

Table 4.4 Number of occupants with health history sensitive to IAQ on each floor

Characteristics	Total		Floor											
	N	%	7th		8th		9th		10th		11th		12th	
			n	%	n	%	n	%	n	%	N	%	n	%
Occupants' health history														
Cold	79	27.62	7	18.42	8	8.60	13	13.54	13	14.77	21	22.34	17	21.25
Dust allergy	71	24.83	4	10.53	9	9.68	14	14.58	9	10.23	23	24.47	12	15.00
Migraine	71	24.83	4	10.53	9	9.68	14	14.58	9	10.23	23	24.47	12	15.00
Eye allergy	62	21.68	4	10.53	5	5.38	7	7.29	7	7.95	20	21.28	19	23.75
Sinus	35	12.24	3	7.89	5	5.38	8	8.33	5	5.68	7	7.45	7	8.75
Dermatitis	22	7.69	4	10.53	1	1.08	3	3.13	3	3.41	6	6.38	5	6.25
Allergies	11	3.85	2	5.26	2	2.15	1	1.04	2	2.27	1	1.06	3	3.75
Asthma	2	0.70	0	0	0	0	0	0	0	0	2	2.13	0	0
Tuberculosis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Contact lenses wearing	84	29.37	4	10.53	14	15.05	12	12.5	13	14.77	19	20.21	22	27.5
Smoke	46	16.08	1	2.63	9	9.68	7	7.29	8	9.09	14	14.89	7	8.75

* Number of occupants on each floor; 7^{th}(38), 8^{th}(93), 9^{th}(96), 10^{th}(88), 11^{th}(94), and 12^{th}(80)

Table 4.5 Satisfaction level for IAQ/IEQ parameter

IAQ and IEQ parameters	Satisfaction level	Total		Floor*											
				7th		8th		9th		10th		11th		12th	
		N	%	n	%	n	%	n	%	n	%	n	%	n	%
Respirable particulates	Slightly	23	8.04	2	5.26	3	3.23	2	2.08	1	1.14	10	10.64	5	6.25
	Low	66	23.08	6	15.79	7	7.53	12	12.5	8	9.09	16	17.02	17	21.25
	Medium	148	51.75	13	34.21	24	25.81	33	34.38	16	18.18	37	39.36	25	31.25
	High	45	15.73	2	5.26	5	5.38	8	8.33	10	11.36	11	11.70	9	11.25
	Very high	4	1.40	0	0	2	2.15	0	0	1	1.14	0	0	1	1.25
Odor	Slightly	15	5.24	1	2.63	1	1.08	0	0	1	1.14	8	8.51	4	5
	Low	43	15.03	5	13.16	7	7.53	6	6.25	3	3.41	13	13.83	9	11.25
	Medium	169	59.09	16	42.11	25	26.88	36	37.5	21	23.86	41	43.62	30	3.75
	High	52	18.18	1	2.63	6	6.45	12	12.5	9	10.23	11	11.70	13	16.25
	Very high	7	2.45	0	0	2	2.15	1	1.05	2	2.27	1	1.06	1	1.25
Ventilation rate	Slightly	34	11.89	1	2.63	4	4.30	5	5.21	3	3.41	12	12.77	9	11.25
	Low	132	46.15	9	23.68	22	23.66	24	25	14	15.91	32	34.04	31	38.75
	Medium	89	31.12	12	31.58	10	10.75	21	21.88	13	14.77	22	23.40	11	13.75
	High	26	9.09	1	2.63	3	3.23	5	5.21	5	5.68	7	7.45	5	6.25
	Very high	5	1.75	0	0	2	2.15	0	0	1	1.14	1	1.06	1	1.25
Temperature &RH	Slightly	33	11.54	0	0	3	3.23	4	4.17	8	9.09	5	5.32	13	16.25
	Low	125	43.71	7	18.42	18	19.35	30	3.13	13	14.77	33	35.11	24	30
	Medium	99	34.62	15	39.47	17	18.28	16	16.67	9	10.23	27	28.72	15	18.75
	High	22	7.69	1	2.63	2	2.15	4	4.17	5	5.68	6	6.38	4	5
	Very high	7	2.45	0	0	1	1.08	1	1.04	1	1.14	3	3.19	1	1.25
Light	Slightly	7	2.45	0	0	1	1.08	0	0	1	1.14	3	3.19	2	2.5
	Low	65	22.73	3	7.89	13	13.98	11	11.46	19	21.59	14	14.89	28	35
	Medium	97	33.92	7	18.42	16	17.20	13	13.54	17	19.32	28	29.79	24	30
	High	97	3.92	7	18.42	16	17.20	13	13.54	17	19.32	20	21.28	24	30
	Very high	20	0.70	0	0	3	3.23	4	4.17	2	2.27	9	9.57	2	2.5
Sound	Slightly	5	1.75	0	0	0	0	0	0	0	0	4	4.26	1	1.25
	Low	68	23.78	4	10.53	10	10.75	16	16.67	12	13.64	15	15.96	11	13.75
	Medium	19	6.64	10	26.32	17	18.28	21	21.88	13	14.77	35	37.23	23	28.75
	High	80	2.79	9	23.68	12	12.90	15	15.63	7	7.95	19	20.21	18	22.5
	Very high	14	4.89	0	0	2	2.15	3	3.13	4	4.55	1	1.06	4	5

* Number of occupants on each floor; 7th(38), 8th(93), 9th(96), 10th(88), 11th(94), and 12th(80)

4.4 The prevalence of occupants' symptoms related to IAQ/IEQ

The result was illustrated in table 4.6-4.7. The top three prevalence rates were back pain, nose irritation and headache, i.e. 3.85%, 3.50% and 3.50% respectively. The highest frequency of back pain and headache were found on 7th floor 5.26% and 7.89%. The rate of nose irritation was highest on the 10th floor (4.55%).

Table 4.6 The prevalence of IAQ/IEQ related symptoms

Occupants' symptom	Total		Floor											
	N	%	7th		8th		9th		10th		11th		12th	
			n	%	n	%	n	%	n	%	n	%	n	%
Back pain	11	3.85	2	**5.26**	1	1.08	5	5.21	2	2.27	1	1.06	0	0
Nose irritation	10	3.50	1	2.63	1	1.08	3	3.13	4	**4.55**	1	1.06	0	0
Headache	10	3.50	3	**7.89**	0	0	5	5.21	2	2.27	0	0	0	0
Eye irritation	7	2.45	0	0	0	0	4	4.17	3	3.41	0	0	0	0
Cold/Flu	7	2.45	2	5.26	1	1.08	2	2.08	2	2.27	0	0	0	0
Exhaust	5	1.75	0	0	1	1.08	0	0	3	3.41	1	1.06	0	0
Dry mouth	4	1.40	0	0	1	1.08	0	0	2	2.27	1	1.06	0	0
Fever	4	1.40	0	0	0	0	2	2.08	2	2.27	0	0	0	0
Dry skin	3	1.05	0	0	1	1.08	1	1.04	1	1.14	0	0	0	0
Throat irritation	2	0.70	0	0	1	1.08	0	0	1	1.14	0	0	0	0
Vomit	2	0.70	0	0	0	0	1	1.04	0	0	1	1.06	0	0
Shortness of breath	1	0.35	0	0	0	0	0	0	0	0	1	1.06	0	0
Dizziness	1	0.35	0	0	0	0	0	0	1	1.14	0	0	0	0
Total no. of occupants' symptoms	31	10.84	3	1.05	3	1.05	14	**4.90**	7	2.45	4	1.40	0	0

* Number of occupants on each floor; 7th(38), 8th(93), 9th(96), 10th(88), 11th(94), and 12th(80)

Table 4.7 The prevalence of IAQ/IEQ related symptoms by zone

Occupant's symptoms	Total		7th floor Zone 2 n=38		8th floor Zone 1 n=13		8th floor Zone 2 n=40		8th floor Zone 3 n=40		9th floor Zone 1 n=19		9th floor Zone 2 n=32		9th floor Zone 3 n=45		10th floor Zone1 n=32		10th floor Zone 2 n=24		10th floor Zone 3 n=32	
	N	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
<u>Back pain</u>	11	3.85	2	5.26	1	7.69	0	0	0	0	3	15.79	0	0	2	4.44	0	0	1	4.17	1	3.13
<u>Nose irritation</u>	10	3.50	1	2.63	1	7.69	0	0	0	0	2	10.53	1	3.13	0	0	2	6.25	1	4.17	1	3.13
<u>Headache</u>	10	3.50	3	7.89	0	0	0	0	0	0	2	10.53	1	3.13	2	4.44	0	0	2	8.33	0	0
Eye irritation	7	2.45	0	0	0	0	0	0	0	0	2	10.53	1	3.13	1	2.22	1	3.13	1	4.17	1	3.13
Cold/Flu	7	2.45	2	5.26	1	7.69	0	0	0	0	1	5.26	0	0	1	2.22	0	0	1	4.17	1	3
Exhaust	5	1.75	0	0	1	7.69	0	0	0	0	0	0	0	0	0	0	0	0	1	4.17	2	6.25
Dry mouth	4	1.40	0	0	1	7.69	0	0	0	0	0	0	0	0	0	0	0	0	1	4.17	1	3.13
Fever	4	1.40	0	0	0	0	0	0	0	0	1	5.26	0	0	1	2.22	0	0	1	4.17	1	3.13
Dry skin	3	1.05	0	0	1	7.69	0	0	0	0	0	0	1	3.13	0	0	0	0	1	4.17	0	0
Throat irritation	2	0.70	0	0	1	7.69	0	0	0	0	0	0	0	0	0	0	0	0	1	4.17	0	0
Vomit	2	0.70	0	0	0	0	0	0	0	0	0	0	0	0	1	2.22	0	0	0	0	0	0
Shortness of breath	1	0.35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dizziness	1	0.35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3.13
Total no. of occ.'symptoms	31	10.84	3	1.05	1	0.35	2	0.70	0	0	7	**<u>2.45</u>**	4	1.40	3	1.05	2	0.70	2	0.70	3	1.05

Table 4.7 The prevalence of IAQ/IEQ related symptoms by zone (con’t)

Occupants' symptoms	11th floor						12th floor					
	Zone 1 n=22		Zone 2 n=32		Zone 3 n=40		Zone 1 n=26		Zone 2 n=27		Zone 3 n=27	
	N	%	n	%	n	%	n	%	n	%	n	%
Back pain	0	0	0	0	1	2.5	0	0	0	0	0	0
Nose irritation	0	0	0	0	1	2.5	0	0	0	0	0	0
Headache	0	0	0	0	0	0	0	0	0	0	0	0
Eye irritation	0	0	0	0	0	0	0	0	0	0	0	0
Cold/Flu	0	0	0	0	0	0	0	0	0	0	0	0
Exhaust	0	0	0	0	1	2.5	0	0	0	0	0	0
Dry mouth	0	0	0	0	1	2.5	0	0	0	0	0	0
Fever	0	0	0	0	0	0	0	0	0	0	0	0
Dry skin	0	0	0	0	0	0	0	0	0	0	0	0
Throat irritation	0	0	0	0	0	0	0	0	0	0	0	0
Vomit	0	0	0	0	1	2.5	0	0	0	0	0	0
Shortness of breath	0	0	0	0	1	2.5	0	0	0	0	0	0
Dizziness	0	0	0	0	0	0	0	0	0	0	0	0
Total no. of occ' symptoms	1	0.35	0	0	3	1.05	0	0	0	0	0	0

4.5 IAQ/IEQ measurement in the office building

The measured IAQ/IEQ parameters were respirable particulates, TVOCs, formaldehyde, ozone, carbon dioxide, ventilation rate, temperature, relative humidity, light, and noise. The results were illustrated in table 4.8. Most of measured parameters are complied with the standards, except for ventilation rates and ozone. In some areas ventilation rate and ozone exceeded the recommended standards. According to ventilation rate, the results were illustrated in table 4.9. The room/areas where ventilation rates did not complied with ASHRAEs are illustrated in table 4.9. The rooms with lowest ventilation rate on each floor are 3.16 cfm/person on 7th floor zone 2, 10.01 cfm/person on 8th floor zone 3, 10.11 cfm/person on 9th floor zone 1, 20.09 cfm/person on 10th floor zone 3, 11.67 cfm/person on 11th floor zone 3 and 20.07 cfm/person on 12th floor zone 3.

Table 4.8 IAQ/IEQ measurement on the 7th to 12th floor

Floor	Zone	No. of occupants at measurement time	Respirable particulates (mg/m^3)	TVOCs (ppm)	Formaldehyde (ppm)	Ozone (ppm)	Carbon dioxide (ppm)	Ventilation rate* (cfm/person)	Temperature (°C)	Relative humidity (%)	Noise (dBA)
			OSHA	Singapore	Singapore	ACGIH	ASHRAE	ASHRAE	ASHRAE	ASHRAE	OSHA
Recommendation value		-	5	3	0.1	0.05	1000	20	23-25	60-80	80
7th	2	38	0.37	0	0	0	598	3.16	23.9	74	57.8
8th	1	13	0.29	0	0	0	534	31.66	22.4	79.6	55.3
	2	40	0.31	0	0	0	626	15.18	24.1	73.2	54.1
	3	40	0.33	0	0	0	693	10.42	23.9	72.5	62.3
9th	1	19	0.32	0	0	0	583	12.63	23.3	69.7	51
	2	32	0.31	0	0	0	551	16.84	23.8	68.2	59.1
	3	45	0.35	0	0	0	585	16.23	22.9	77.9	61.2
10th	1	32	0.23	0	0.08	0	550	28.41	23.6	67.3	54.5
	2	24	0.25	0	0	0	523	32.52	23.4	66.1	53.4
	3	32	0.29	0	0	0	560	22.33	23.7	64.3	50.1
11th	1	22	0.42	0	0	0	690	23.13	23.0	72.1	56.4
	2	32	0.27	0	0.02	0	656	24.93	24.1	65.5	52.1
	3	40	0.48	0	0.01	0.09	652	14.86	23.3	65.4	55.4
12th	1	26	0.25	0	0	0	609	45.48	23.4	67.9	56.7
	2	27	0.23	0	0	0	589	32.39	23.3	69.4	55.2
	3	27	0.39	0	0	0	583	21.79	23.2	68.9	54.3
Min-Max		13-45	0.23-0.48	0	0-0.08	0-0.09	523-693	3.16-32.52	22.40-24.10	64.30-79.60	50.10-62.30
Average ± S.D.		31±8.986	0.32±0.07	0	0.007±0.020	0.006±0.023	598.88±52.31	20.94±8.87	23.46±0.46	70.13±4.45	55.56±3.56

* The calculation of ventilation rate shown as appendix I, ** the lighting measurement result shown as appendix J

Table 4.9 The ventilation rate measurement on the 7th to 12th floor*

Floor/zone	No.	Type of room	Ventilation rate (cfm/person)	ASHRAE recommendation value (cfm/person)
7/2	1	Staff area 1	3.16	20
	2	Staff area 2	3.16	20
	3	Training room 1	24.02	20
	4	Training room 2	24.02	20
	5	Pantry	15.18	20
	6	Xerox room	15.16	20
8/1	1	Staff area 1	31.66	20
	2	Meeting room 1	25.43	20
	3	Meeting room 2	25.45	20
	4	Library	35.00	20
	5	Management room	23.15	20
	6	Xerox room	29.60	20
8/2	1	Meeting room 1	15.03	20
	2	Management room 1	17.04	20
	3	Management room 2	19.35	20
	4	Management room 3	20.07	20
	5	Staff area 1	15.18	20
	6	Staff area 2	13.05	20
	7	Staff area 3	14.34	20
	8	Pantry	19.08	20
8/3	1	Staff area 1	10.13	20
	2	Management room 1	11.93	20
	3	Management room 2	11.34	20
	4	Staff area 2	10.42	20
	5	Management room 3	11.23	20
	6	Management room 4	11.00	20
	7	Staff area 3	10.09	20
	8	Pantry	10.21	20
	9	Xerox	10.01	20

* See appendix J; the ventilation measurement layout

Table 4.9 The ventilation rate measurement on the 7th to 12th floor* (con't)

Floor/zone	No.	Type of room	Ventilation rate (cfm/person)	ASHRAE recommendation value (cfm/person)
9/1	1	Staff area 1	12.63	20
	2	Management room 1	12.02	20
	3	Management room 2	12.21	20
	4	Management room 3	12.13	20
	5	Xerox room	10.11	20
	6	Nurse service room	15.09	20
	7	Management room 5	13.20	20
	8	Staff area 2	11.03	20
9/2	1	Management room 1	15.76	20
	2	Management room 2	15.34	20
	3	Management room 3	20.09	20
	4	Meeting room	16.02	20
	5	Staff area 1	17.09	20
	6	Staff area 2	16.84	20
	7	Staff area 3	18.00	20
	8	Pantry	16.20	20
9/3	1	Management room 1	16.11	20
	2	Management room 2	17.00	20
	3	Management room 3	18.02	20
	4	Management room 4	16.45	20
	5	Management room 5	17.09	20
	6	Staff area 1	16.23	20
	7	Staff area 2	15.22	20
	8	Management room 6	15.25	20
	9	Management room 7	16.09	20
	10	Staff area 3	16.23	20
	11	Xerox room	17.09	20
	12	Pantry	17.55	20

* See appendix J; the ventilation measurement layout

Table 4.9 The ventilation rate measurement on the 7th to 12th floor* (con't)

Floor/zone	No.	Type of room	Ventilation rate (cfm/person)	ASHRAE recommendation value (cfm/person)
10/1	1	Meeting room	27.88	20
	2	Xerox room	25.78	20
	3	Management room 1	27.09	20
	4	Staff area 1	28.41	20
	5	Management room 2	25.34	20
	6	Management room 3	26.75	20
	7	Management room 4	26.44	20
	8	Staff area 2	27.02	20
10/2	1	Staff area 1	30.08	20
	2	Management room 1	29.67	20
	3	Management room 2	33.34	20
	4	Management room 3	32.09	20
	5	Meeting room	32.67	20
	6	Staff area 2	32.52	20
	7	Management room 4	30.12	20
	8	Pantry	30.07	20
10/3	1	Staff area 1	29.06	20
	2	Meeting room	22.45	20
	3	Xerox room	21.00	20
	4	Staff area 2	22.33	20
	5	Management room 1	21.09	20
	6	Staff area 3	22.11	20
	7	Pantry	20.09	20

* See appendix J; the ventilation measurement layout

Table 4.9 The ventilation rate measurement on the 7th to 12th floor* (con't)

Floor/zone	No.	Type of room	Ventilation rate (cfm/person)	ASHRAE recommendation value (cfm/person)
11/1	1	Staff area 1	23.13	20
	2	Xerox room	22.11	20
	3	Management room 1	20.09	20
	4	Management room 2	20.12	20
	5	Management room 3	20.23	20
	6	Staff area 2	22.25	20
	7	War room	20.09	20
11/2	1	Staff area 1	24.09	20
	2	Management room 1	22.11	20
	3	Management room 2	21.98	20
	4	Management room 3	21.39	20
	5	Management room 4	20.31	20
	6	Management room 5	20.32	20
	7	Staff area 2	24.93	20
	8	Pantry	23.19	20
11/3	1	Meeting room 1	20.13	20
	2	Staff area 1	19.11	20
	3	Meeting room 2	17.03	20
	4	Staff area 2	14.86	20
	5	Management room 1	12.09	20
	6	Management room 2	11.67	20
	7	Staff area 3	15.98	20
	8	Xerox room	19.89	20
	9	Pantry	16.09	20

* See appendix J; the ventilation measurement layout

Table 4.9 The ventilation rate measurement on the 7th to 12th floor* (con't)

Floor/zone	No.	Type of room	Ventilation rate (cfm/person)	ASHRAE recommendation value (cfm/person)
12/1	1	Staff area 1	45.48	20
	2	Xerox room	30.09	20
	3	Management room 1	29.09	20
	4	Management room 2	27.24	20
	5	Management room 3	25.08	20
	6	Staff area 2	29.37	20
12/2	1	Staff area 1	32.39	20
	2	Management room 1	30.09	20
	3	Management room 2	29.89	20
	4	Management room 3	25.89	20
	5	Meeting room 1	30.09	20
	6	Management room 4	20.08	20
	7	Management room 5	23.09	20
	8	Management room 6	22.11	20
	9	Management room 7	20.34	20
	10	Management room 8	21.09	20
	11	Management room 9	20.34	20
	12	Management room 10	22.19	20
	13	Staff area 2	24.09	20
	14	Pantry	23.06	20
12/3	1	Meeting room	22.09	20
	2	Management room 1	21.00	20
	3	Management room 2	22.01	20
	4	Management room 3	21.41	20
	5	Management room 4	23.09	20
	6	Staff area 1	21.79	20
	7	Management room 5	22.08	20
	8	Management room 6	21.98	20
	9	Management room 7	22.06	20
	10	Management room 8	22.00	20
	11	Management room 9	20.07	20
	12	Staff area 2	26.09	20
	13	Xerox room	21.25	20
	14	Pantry	21.53	20

* See appendix J; the ventilation measurement layout

4.6 The correlation between IAQ/IEQ and occupants' symptoms

The number of subjects who may have the IAQ/IEQ related symptoms was 31 out of 286. The correlation between IAQ/IEQ and occupants' symptoms was presented in table 4.9. The pairs with significant correlation are underlined. The ventilation rate correlated with overall symptoms at significant level 0.05 (p-value 0.001). The prevalence of overall symptoms was highest (18.3%) when ventilation rate was lower than 20 cfm/person (standard for general office). The symptoms with the highest prevalence rates were headache (5%) and nose irritation (4.2%) while the other significant correlated pairs are CO_2 and dizziness; CO_2 and exhaust; and CO_2 and dry mouth. However, the cases of such symptoms were quite low, i.e. only 1, 2 and 3 for dizziness, dry mouth and exhaust respectively.

Table 4.10 The correlation between IAQ/IEQ and occupants' symptoms

IAQ/IEQ Parameters	Range	Overall symptoms		Headache		Nose irritation		Cold/Flu		Dizziness		Exhaust		Dry mouth		Vomit		Eye irritation		Throat irritation		Shortness of breath		Dry skin		Back pain		Fever	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Respirable	0.2-0.3 mg/m^3	7	6.8	3	2.9	5	4.9	2	1.9	1	1.0	3	2.9	2	1.9	0	0	3	2.9	1	1.0	0	0	1	1.0	3	2.9	2	1.9
particulates	0.3-0.4 mg/m^3	20	15.9	6	4.8	5	4.0	5	4.0	0	0	1	0.8	1	0.8	0	0	4	3.2	1	0.8	0	0	2	1.6	7	5.6	2	1.6
	0.4-0.5 mg/m^3	4	7.0	1	1.8	3	5.3	2	3.5	0	0	2	3.5	1	1.8	1	1.8	0	0	0	0	1	1.8	0	0	1	1.8	0	0
	P-value$^{(a)}$		0.052		0.545		0.911		0.672		0.410		0.381		0.738		0.133		0.406		0.768		0.133		0.618		0.384		0.588
TVOCs	0 ppm	31	10.8	10	3.5	13	4.5	9	3.1	1	0.3	6	2.1	4	1.4	1	0.3	7	2.4	2	0.7	1	0.3	3	1.0	11	3.8	4	1.4
	P-value$^{(b)}$	-		-		-		-		-		-		-		-		-		-		-		-		-		-	
Formaldehyde	0 ppm	27	12.1	9	4.0	10	4.5	6	2.7	0	0	3	1.3	3	1.3	1	0.4	6	2.7	2	0.9	1	0.4	3	1.3	10	4.5	3	1.3
	0-0.1 ppm	4	6.5	1	1.6	3	4.8	3	4.8	1	1.6	3	4.8	1	1.6	0	0	1	1.6	0	0	0	0	0	0	1	1.6	1	1.6
	P-value$^{(a)}$		0.209		0.362		0.900		0.389		0.057		0.089		0.871		0.598		0.631		0.455		0.598		0.360		0.301		0.871
Ozone	<0.05 ppm	30	12.2	9	3.7	11	4.5	7	2.8	1	0.4	5	2.0	4	1.6	1	0.4	7	2.8	2	0.8	1	0.4	3	1.2	11	4.5	4	1.6
	>0.05 ppm	1	2.5	1	2.5	2	5.0	2	5.0	0	0	1	2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	P-value$^{(a)}$		0.067		0.711		0.882		0.469		0.686		0.848		0.417		0.686		0.280		0.567		0.686		0.483		0.173		0.417
Carbon-	<600	4	11.1	0	0	2	5.6	2	5.6	1	2.8	3	8.3	2	5.6	0	0	1	2.8	1	2.8	0	0	1	2.8	2	5.6	1	2.8
dioxide	600-800	27	10.8	10	4.0	11	4.4	7	2.8	0	0	3	1.2	2	0.8	1	0.4	6	2.4	1	0.4	1	0.4	2	0.8	9	3.6	3	1.2
	P-value$^{(a)}$		0.955		0.222		0.756		0.376		**0.008**		**0.005**		**0.023**		0.704		0.891		0.109		0.704		0.276		0.568		0.451
Ventilation	<20 cfm/ Person	22	18.3	6	5.0	5	4.2	4	3.3	0	0	1	0.8	1	0.8	1	0.8	4	3.3	0	0	1	0.8	1	0.8	7	5.8	2	1.7
rate	>20 cfm/ person	9	5.4	4	2.4	8	4.8	5	3.0	1	0.6	5	3.0	3	1.8	0	0	3	1.8	2	1.2	0	0	2	1.2	4	2.4	2	1.2
	P-value$^{(a)}$		**0.001**		0.239		0.794		0.878		0.394		0.205		0.489		0.239		0.410		0.228		0.239		0.761		0.137		0.743

Table 4.10 The correlation between IAQ/IEQ and occupants' symptoms (con't)

Parameters	Range	Overall symptoms		Headache		Nose irritation		Cold/Flu		Dizziness		Exhaust		Dry mouth		Vomit		Eye irritation		Throat irritation		Shortness of breath		Dry skin		Back pain		Fever	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Temperature	<23°C	10	9.6	5	4.8	6	5.8	4	3.8	0	0	2	1.9	1	1.0	0	0	3	2.9	1	1.0	0	0	1	1.0	4	3.8	2	1.9
	23-25 °C	21	11.5	5	2.7	7	3.8	5	2.7	1	0.5	4	2.2	3	1.6	1	0.5	4	2.2	1	0.5	1	0.5	2	1.1	7	3.8	2	1.1
	P-value[(a)]		0.615		0.361		0.453		0.609		0.449		0.876		0.634		0.449		0.718		0.687		0.449		0.913		1.000		0.568
RH	60-80%	29	10.6	10	3.7	11	4.0	9	3.3	1	0.4	6	2.2	4	1.5	1	0.4	6	2.2	2	0.7	1	0.4	3	1.1	11	4.0	4	1.5
	<60%	2	15.4	0	0	2	15.4	0	0	0	0	0	0	0	0	0	0	1	7.7	0	0	0	0	0	0	0	0	0	0
	P-value[(a)]		0.589		0.482		0.055		0.506		0.827		0.589		0.660		0.827		0.210		0.757		0.827		0.704		0.460		0.650
Light	600-700 lux	17	12.4	4	2.9	7	5.1	5	3.6	0	0	2	1.5	1	0.7	0	0	4	2.9	1	0.7	0	0	1	0.7	5	3.6	2	1.5
	>700 lux	14	9.4	6	4.0	6	4.0	4	2.7	1	0.7	4	1.5	3	2.0	1	0.7	3	2.0	1	0.7	1	0.7	2	1.3	6	4.0	2	1.3
	P-value[(a)]		0.413		0.611		0.661		0.640		0.337		0.470		0.356		0.337		0.620		0.952		0.337		0.612		0.868		0.933
Noise	0-50 dBA	2	14.3	0	0	2	14.3	0	0	0	0	0	0	0	0	0	0	1	7.1	0	0	0	0	0	0	0	0	0	0
	51-60 dBA	23	10.0	9	3.9	9	3.9	7	3.0	1	0.4	5	2.2	3	1.3	1	0.4	4	1.7	1	0.4	1	0.4	2	0.9	8	3.5	3	1.3
	61-80 dBA	6	14.3	1	2.4	2	4.8	2	4.8	0	0	1	2.4	1	2.4	0	0	2	4.8	1	2.4	0	0	1	2.4	3	7.1	1	2.4
	P-value[(a)]		0.652		0.677		0.194		0.663		0.885		0.851		0.776		0.885		0.257		0.360		0.885		0.626		0.391		0.776

(a) Significant at level 0.01, (b)Pearson chi-square, - no statistics are computed because sampling TVOCs is a constant.

4.7 The correlation between occupants' symptoms and occupants' satisfactions

The correlation between occupants' symptoms and occupants' satisfactions was presented in table 4.11. The pairs with significant correlation are underlined. The cold/flu correlated with occupants' satisfactions of odor and ventilation at significant level 0.05 with p-value 0.049, 0.019 respectively and correlation coefficient 0.357 and 0.419 respectively.

The vomit correlated with occupants' satisfactions of ventilation at significant level 0.01 with p-value 0.005 and correlation coefficient -0.488.

The eye irritation correlated with occupants' satisfactions of light at significant level 0.05 with p-value 0.025 and correlation coefficient -0.403.

The shortness of breath correlated with occupants' satisfactions of odor and ventilation at significant level 0.01 with p-value 0.005 and 0.001 respectively and correlation coefficient -0.496 and -0.550 respectively as well as occupants' satisfactions of temperature at significant level 0.05 with p-value 0.036 and correlation coefficient -0.378.

The fever correlated with occupants' satisfaction of ventilation at significant level 0.05 with p-value 0.029 and correlation coefficient 0.393.

However, the cases of such symptoms were quite low, i.e. only 1, 2, 4 and 7 for shortness of breath, vomit, fever and cold and eye irritation.

Table 4.11 The correlation between occupants' symptoms and occupants' satisfactions

Occupants' symptoms	Degree of occupants' satisfactions***											
	Respirable particulates		Odor		Ventilation		Temperature		Light		Noise	
	Correlation Coefficient	P-value	Correlation Coefficient	P-value	Correlation Coefficient	P-value	Correlation Coefficient	P-value	Correlation Coefficient	P-value	Correlation Coefficient	P-value
Headache	0.092	0.624	0.063	0.738	0.228	0.217	0.048	0.799	-0.252	0.172	-0.295	0.107
Nose irritation	0.181	0.331	0.063	0.738	-0.249	0.177	-0.034	0.854	-0.315	0.084	-0.221	0.233
Cold/Flu	0.330	0.070	0.357*	**0.049**	0.419*	**0.019**	0.074	0.693	-0.332	0.068	-0.555**	**0.001**
Dizziness	-0.023	0.903	0.313	0.086	0.081	0.663	0.056	0.765	0.319	0.080	-0.216	0.244
Exhaust	-0.055	0.770	0.105	0.576	-0.209	0.260	0.135	0.471	-0.200	0.280	-0.140	0.452
Dry mouth	-0.172	0.355	0.092	0.624	-0.161	0.387	0.004	0.984	0.211	0.254	-0.144	0.440
Vomit	-0.202	0.276	-0.326	0.074	-0.488**	**0.005**	-0.388*	0.031	-0.265	0.150	-0.027	0.884
Eye irritation	-0.067	0.719	-0.099	0.595	0.063	0.736	-0.293	0.110	-0.403*	**0.025**	-0.472**	**0.007**
Throat irritation	-0.033	0.861	0.257	0.163	0.117	0.530	0.237	0.200	-0.265	0.150	-0.027	0.884
Shortness of breath	-0.254	0.162	-0.496**	**0.005**	-0.550**	**0.001**	-0.378*	**0.036**	-0.352	0.052	-0.019	0.919
Dry skin	-0.041	0.828	0.239	0.195	0.146	0.433	0.230	0.213	-0.129	0.488	0.083	0.655
Back pain	0.081	0.664	0.077	0.680	0.020	0.915	-0.093	0.618	-0.438**	**0.014**	-0.513**	**0.003**
Fever	-0.172	0.355	-0.050	0.787	0.393*	**0.029**	0.232	0.208	-0.476**	**0.007**	-0.247	0.180
Mean ± S.D.	2.86±0.76		3.06±0.56		2.18±0.76		2.15±0.69		2.58±1.00		2.58±0.87	

*** Degree of satisfaction refers to 1.8.16, ** Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level

CHAPTER V
DISCUSSION

5.1 The prevalence of occupants' symptoms related to IAQ/IEQ and result of IAQ/IEQ measurement in the office building

The top three frequency symptoms of the occupants were back pain, nose irritation, and headache which were comparable to the study in the office building by Sasithorn Narongsak (61) and NIOSH (57). However, the prevalence rate of such symptoms was lower by more than half of those two studies. The prevalence rate of back pain, nose irritation and headache were 3.85%, 3.50% and 3.50% respectively. The reason for this could be that the contaminant concentrations in this study were lower both than the recommended standards e.g. OSHA, Ministry of Environment Singapore, ACGIH, ASHRAE, Thai law and those found in the two studies. The back pain, the highest prevalence of occupants' symptoms was mostly found in Call Center on the 7^{th} floor. It seems to be caused by the nature of work, static and tedious, rather than IAQ/IEQ problem. The headache was mostly found on the 7^{th} floor where the ventilation rate was 3.16 cfm/person, therefore it may potentially be the cause of symptom. The nose irritation was mostly found on the 10^{th} floor at zone 1 where the formaldehyde concentration was 0.08 ppm. Formaldehyde, as we knew that it can cause nose irritation. Therefore, it may potentially cause nose irritation.

Calculation of odd ratio, to consider about the symptoms occurred with the result of IAQ/IEQ in the studied zone. There were 31 persons who had the symptoms related to IAQ/IEQ. Among these 21 of them work in the areas where some of measured parameter IAQ exceeded the standard.

5.2 The correlation between IAQ/IEQ and occupants' symptoms

There were several significant correlations between IAQ/IEQ with occupants' symptoms, i.e.

The ventilation rate correlated significantly with the prevalence of the overall symptoms. This relationship was contrary direction, i.e. the less ventilation rate the higher the prevalence of the overall symptoms. Due to the ventilation rate may cause building up of indoor contaminants thus inadequate ventilation may cause sick building syndrome (3). The result of this study pointed out that the ventilation rate may potentially cause high prevalence of IAQ/IEQ symptoms significantly.

There were significant relationship between carbon dioxide and dry mouth, exhaust and dizziness. However, there is no such relation explained anywhere else. Furthermore, there were only three people with such symptoms; case # 1 is working on the 10^{th} floor zone 1, case # 2 on the 11^{th} floor zone 1 and case # 3 on the 8^{th} floor zone 3. The cases are scatter on different floor, therefore the three parameters are not real correlation.

5.3 The correlation between occupants' symptoms and occupants' satisfactions

There were several significant correlations between IAQ/IEQ with occupants' symptoms, i.e.

Cold/flu correlated with occupants' satisfactions of odor and ventilation. There were 7 cases of cold/flu on the 7^{th} floor zone 2, 8^{th} floor zone 1 and 9^{th} floor zone 1 and zone 3. All of them unsatisfied with odor and ventilation. However, IAQ/IEQ parameters in such area did not exceed the standard, while the ventilation rates were lower than ASHRAE recommendation.

Vomit and occupants' satisfactions of ventilation, the cases of such symptoms quite low, i.e. only 2 cases on the 9^{th} floor zone 3 and 11^{th} floor zone 3 where the ventilation rate was lower than ASHRAE recommendation.

Eye irritation and occupants' satisfactions of light. There were 7 cases work in different location and all wear contact lenses and those found all zone on the

9th floor and 10th floor where the measurement of lighting were complied with Thai standard. Thus, this correlation may obscure relationship.

Shortness of breath and occupants' satisfactions of odor, ventilation and temperature. The cases of such symptoms quite low, i.e. only 1 case on the 11th floor zone 3 where formaldehyde and ozone concentration were found and ventilation rate was lower than ASHRAE recommendation.

Fever and occupants' satisfaction of ventilation, the cases of such symptoms quite low, i.e. only 4 cases on the 9th floor zone 1 and zone 3 where ventilation rate was lower than ASHRAE recommendation and on the 10th floor zone 2 and zone 3 where ventilation rate was complied with ASHRAE recommendation.

So cold/flu, vomit, and shortness of breath were significantly correlated with the satisfaction of ventilation rate ($p\text{-value} < 0.01$).

CHAPTER VI
CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The purpose of this research was to study the prevalence of IAQ/IEQ related symptoms and satisfactions IAQ/IEQ in the office building. The indoor environment parameters i.e. respirable particulates, TVOCs, formaldehyde, ozone, carbon dioxide, temperature, relative humidity, light, and noise were measured. The data of occupants' demographic, history of health, symptoms, and satisfactions were collected from 286 subjects using self-administered questionnaire. The variables were analyzed to identify the relationship of the factors concerned. According to the result of this study were achieved objectives as the following.

The top three prevalence rates of occupants' symptoms were back pain, nose irritation and headache with the rate of 3.85%, 3.50% and 3.50% respectively. According to the highest prevalence rate on each floor, back pain and headache were on the 7th floor with the rate of 5.26% and 7.89% respectively, while the rate of 4.55% was nose irritation found on the 10th floor. Nevertheless, the correlation with IAQ/IEQ was not clearly established. The cases were distributed on different zones and floors.

The results of the IAQ/IEQ measurements i.e. respirable particulates, TVOCs, formaldehyde, ozone, carbon dioxide, ventilation rate, temperature, relative humidity, light, and noise were complied with the international recommendation standards. Except ozone concentration found, on the 11th floor at zone 3 was 0.09 ppm which exceeded the recommendation by ACGIH of 0.05 ppm. The ventilation rates on the 8th floor at zone 2 and zone 3, all zones on the 9th floor, and on the 11th floor at zone 3 were lower than ASHRAE's recommendation.

The relationship between the ventilation rate and overall symptoms correlated at p-value 0.001 while the carbon dioxide and exhaust, dry mouth, dizziness was correlated at p-value 0.005, 0.023 and 0.008 respectively. Due to there is no such relation explained anywhere else about carbon dioxide and such symptoms as well as the cases are scatter on different floor. Therefore this correlation may pseudo relationship. Furthermore, it was found that cold/flu, vomit, and shortness of breath significantly correlated with satisfaction of ventilation (p value < 0.01)

6.2 Recommendation

To determine IAQ/IEQ measurements, the recommendation is presented as the following;

To improve IAQ caused by the contaminants such as ozone on the 11th floor zone 3, replace new equipment to clean the air instead the electrostatic air cleaning was recommended. Due to this equipment was generated ozone.

According to low ventilation on the 7th floor zone 2, it was suggested to install additional air supply diffuser in area where the number of occupants is high or increase air flow to such area. The recommendation of ventilation rate should be 20 cpm/person. Due to the ventilation rate was low, the degree of occupants' satisfactions on ventilation rate and temperature was low and there was significant correlation between ventilation rate and overall symptoms. So the researcher recommended that the application program to control the HVAC system could use, i.e. Building Management System: BMS (see in 1.8.19) which was a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems the program for building facility control was recommended as well. Its core function is to manage the environment within the building and may control temperature, ventilation, carbon dioxide levels and humidity within a building. Using application BMS program may improve the ventilation rate and temperature. And the symptoms which related to those parameter may decrease such as dizziness, exhaust, dry mouth, headache and back pain.

6.3 Recommendation for further study

Further studies should focus on the following issues:

6.3.1 Due to the back pain was highest prevalence rate of occupants' symptoms and the potential cause may be ergonomics problem or psychosocial factors. Hence, ergonomics was highly recommended for further study, especially in Call Center.

6.3.2 The occupants' satisfactions in the office building were mainly studied. Although the HVAC system in the studied building was central air condition, the problems still exist. Thus, for further study the researcher recommend paying more attention on the children. Due to the children are more sensitive to many symptoms than adult, plus kindergartens most of them used the stand alone air condition. Its may affected to the children's health. So the study IAQ/IEQ in kindergartens would highly recommend as well.

6.3.3 Socio-economic and social factors such as financial status, job characteristics, family etc. should be study as well, since they may affect the occupants' satisfaction.

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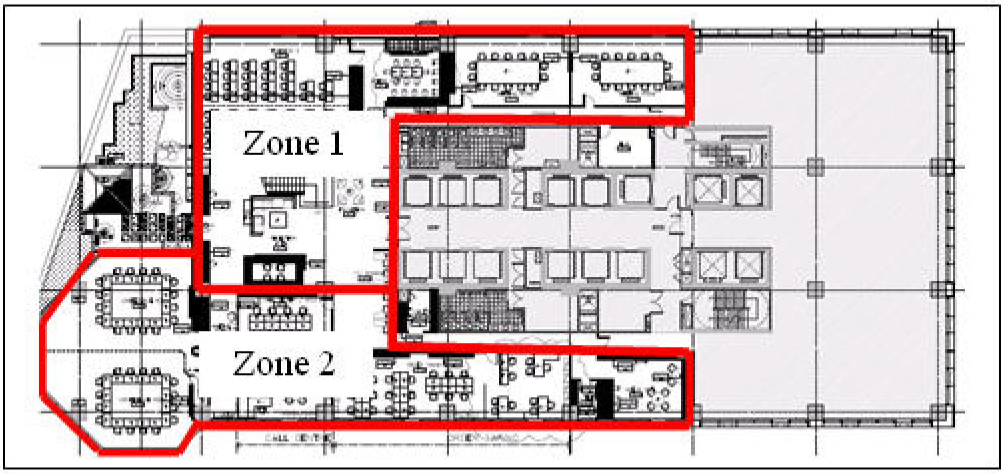
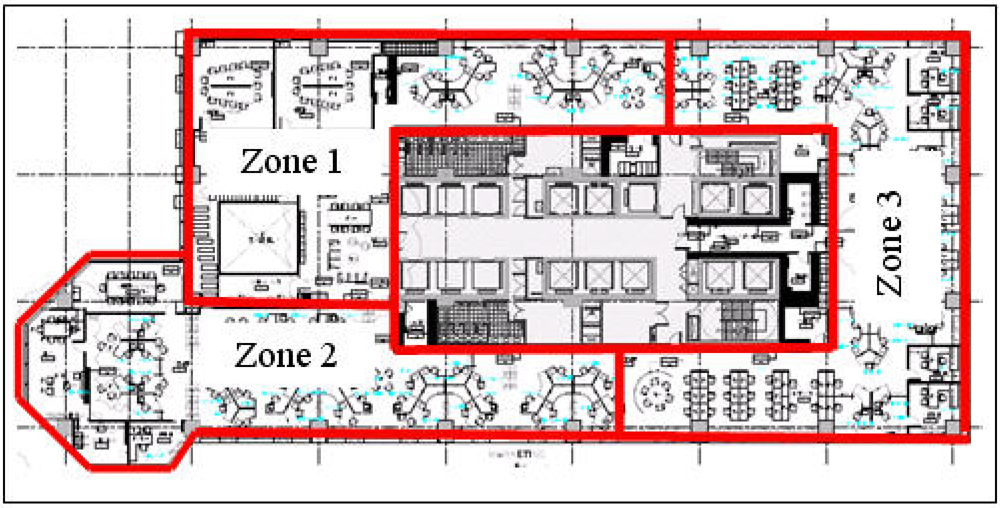
APPENDICES

APPENDIX A

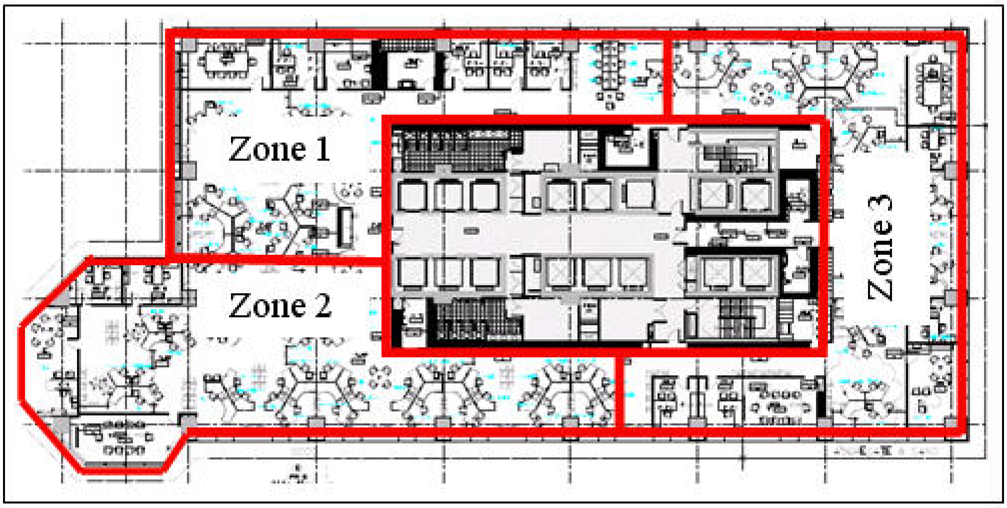
FLOOR / ZONE LAYOUT



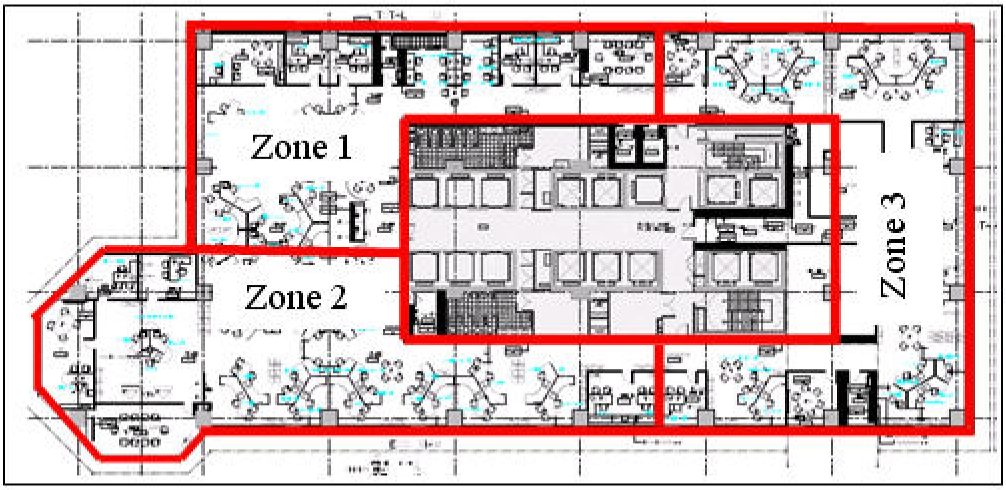
7th floor



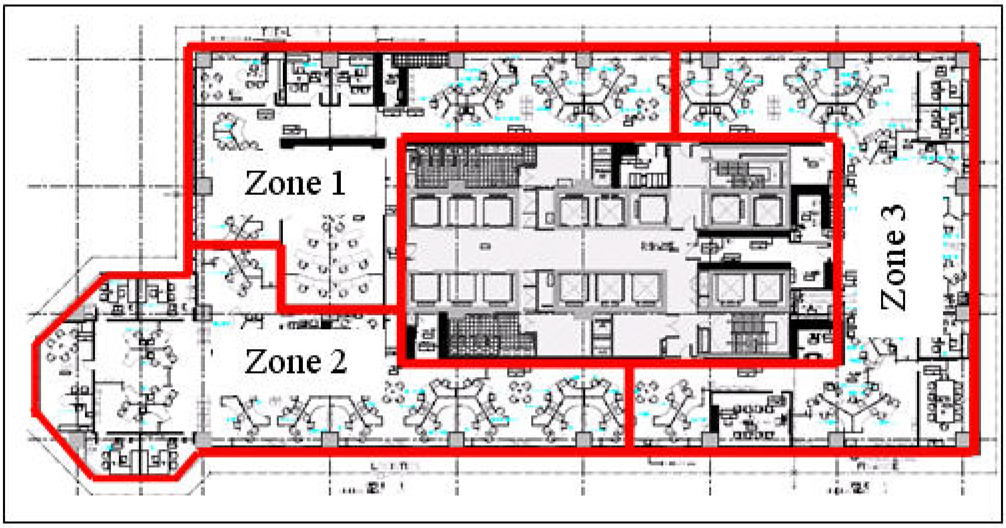
8th floor



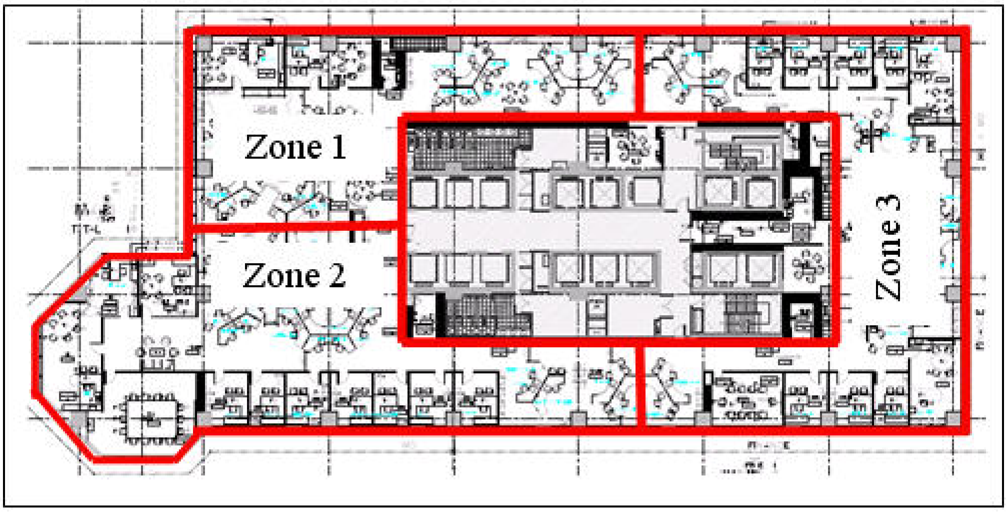
9th floor



10th floor



11th floor



12th floor

APPENDIX B

DOCUMENTARY PROOF OF ETHICAL CLEARANCE

Documentary Proof of Ethical Clearance
Ethics Committee for Human Research
Faculty of Public Health, Mahidol University

Proof Number	MUPH2009-164
Project Title	The Relationship Between Indoor Air Quality and Indoor Environmental Quality with Occupant Symptoms and Satisfactions
Project Number	115/2552
Principal Investigator	Miss Phornthida Yuensuk
Official Address	Master of Science Program in Industrial Hygiene and Safety Faculty of Public Health, Mahidol University 420/1 Rajvithi Road, Bangkok, Thailand

The aforementioned project and informed consent have been reviewed and approved by Ethics Committee for Human Research, according to the Declaration of Helsinki.

(Assoc. Prof. Pipat Luksamijarulkul)
Chairman of Ethics Committee for Human Research

(Assoc. Prof. Phitaya Charupoonphol)
Dean of Faculty of Public Health

Date of Approval : 24 August 2009
Date of Expiration : 23 August 2010

APPENDIX C
INFORMATION SHEET

เอกสารชี้แจงการวิจัยแก่ผู้ยินยอมตนให้ทำการวิจัย

1. ชื่อโครงการวิจัย

ความสัมพันธ์ระหว่างคุณภาพอากาศและสภาพแวดล้อม กับอาการและความพึงพอใจของคนทำงานในอาคารสูง

2. สถานที่ที่ทำการวิจัย

อาคารสูงแห่งหนึ่งที่มีพื้นที่แบ่งให้เช่าเป็นสำนักงาน25 ชั้นและมีบริการห้องพัก (Service Apartment)

3. หัวหน้าโครงการและผู้ร่วมโครงการ และที่อยู่ที่ติดต่อได้

นางสาวพรธิดา ยืนสุข 98 ซอย 11 หมู่บ้านพิบูลย์วัฒนา ถนน พระราม6 เขตพญาไท กรุงเทพฯ โทรศัพท์ 08-9440 1319

E-mail address: phornthida.y@hotmail.com

4. บทนำและเหตุผลในการศึกษาวิจัยของโครงการวิจัยนี้ (อย่างย่อ)

คุณภาพอากาศและสภาพแวดล้อมในสำนักงานนั้นเป็นปัจจัยสำคัญที่มีผลต่อสุขภาพของผู้ที่อาศัยในสำนักงานโดยเฉพาะอย่างยิ่งอาคารสำนักงานที่มีผู้ปฏิบัติงานอย่างต่อเนื่องอย่างน้อย 8 ชั่วโมงต่อวัน 5 วันต่อสัปดาห์ ซึ่งมีผลการศึกษาวิจัยสนับสนุนว่าผู้ที่อาศัยในสำนักงานมีกลุ่มอาการแพ้ที่เกี่ยวข้องกับคุณภาพอากาศและสภาพแวดล้อมอย่างมีนัยสำคัญ อีกทั้งคุณภาพอากาศและสภาพแวดล้อมในสำนักงานยังมีความสัมพันธ์กับความพึงพอใจของผู้ที่อาศัยในสำนักงานอย่างมีนัยสำคัญ ด้วยปัจจัยสภาพแวดล้อมภายในสำนักงานก็มีผลต่อคุณภาพอากาศและสภาพแวดล้อม เช่น ระบบการจัดการอากาศ (HVAC) ซึ่งมีผลต่ออุณหภูมิ ความชื้นและการระบายมลพิษออกจากสำนักงาน, กิจกรรมของผู้ที่ปฏิบัติงานก่อให้เกิดก๊าซคาร์บอนไดออกไซด์, เครื่องใช้สำนักงาน เช่น เครื่องถ่ายเอกสาร คอมพิวเตอร์ สารที่ให้ทำความสะอาดภายในสำนักงาน ตลอดจนวัสดุตกแต่งภายในอาจก่อให้เกิดมลพิษเช่น โอโซน ไนโตรเจนออกไซด์ ความร้อน สารระเหยอินทรีย์ต่างๆ ซึ่ง

ล้วนมีผลกระทบต่อสุขภาพของผู้ปฏิบัติงานภายในสำนักงานทั้งสิ้น จากข้อมูลด้านสุขภาพปี 2550-2551 ในชั้นที่ศึกษาพบสถิติอาการเจ็บป่วยที่พนักงานเป็นมาก 3 ลำดับแรกจาก 10 รายการ คือระบบทางเดินหายใจ, แพ้ที่ผิวหนัง และมีอาการปวดหัว ทั้ง 2 ปี ทั้งนี้ข้อมูลดังกล่าวยังไม่ได้บ่งชี้ว่าเป็นโรคป่วยในอาคาร (Sick Building Syndrome)

ด้วยเหตุนี้ผู้วิจัยมีความตระหนักถึงแนวโน้มของปัญหานี้ จึงมีวัตถุประสงค์ที่จะศึกษาวิจัยปัจจัยด้านคุณภาพอากาศและสภาพแวดล้อม และผลกระทบต่อสุขภาพ ตลอดจนความพึงพอใจที่เกี่ยวเนื่องกับคุณภาพอากาศและสภาพแวดล้อมที่มีในอาคารสำนักงาน เพื่อกำหนดมาตรการในการควบคุมที่เหมาะสมซึ่งทำให้เกิดประสิทธิผลของผู้ปฏิบัติงานในอาคารสำนักงานลักษณะเดียวกันต่อไป

5. วัตถุประสงค์ของโครงการ

1. เพื่อประเมินคุณภาพอากาศและสภาพแวดล้อมภายในสำนักงาน
2. เพื่อศึกษาความชุกของอาการที่เกี่ยวข้องกับคุณภาพอากาศและสภาพแวดล้อมภายในสำนักงานของผู้ปฏิบัติงานในอาคาร
3. เพื่อศึกษาความสัมพันธ์คุณภาพอากาศและสภาพแวดล้อมภายในสำนักงาน กับอาการที่เกี่ยวเนื่องกับคุณภาพอากาศและสภาพแวดล้อมของคนที่ปฏิบัติงานในสำนักงาน
4. เพื่อศึกษาความสัมพันธ์คุณภาพอากาศและสภาพแวดล้อมภายในสำนักงาน กับความพึงพอใจของคนที่อาศัยในสำนักงาน

6. วิธีการวิจัย

รูปแบบการศึกษาจะทำการสอบถามความพึงพอใจต่อคุณภาพอากาศและสภาพแวดล้อมในสำนักงานของผู้ปฏิบัติงานในสำนักงานผ่าน web survey ทางจดหมายอิเลคทรอนิคตรวจวัดคุณภาพอากาศและสภาพแวดล้อมในสำนักงานด้วยเครื่องมือวัดคาร์บอนไดออกไซด์ ฟอล์มัลดีไฮด์ ฝุ่น สารระเหยอินทรีย์ แสง เสียง ความชื้นสัมพัทธ์ อุณหภูมิ อัตราแลกเปลี่ยนอากาศ สอบถามข้อมูลของอาคารและเดินสำรวจสภาพแวดล้อมของอาคาร

7. เหตุผลที่เชิญชวนให้ผู้ยินยอมตนให้ทำการวิจัยเข้าโครงการวิจัย

เนื่องจากปัจจุบันโรคหรือกลุ่มอาการไม่สบายใดๆ จากการอาศัยในอาคารสำนักงานนั้นมีแนวโน้มสูงขึ้น อันมีสาเหตุมาจากปัจจัยหลายด้านที่ยังไม่สามารถชี้จำเพาะได้ คุณภาพอากาศและสภาพแวดล้อมในอาคารก็เป็นปัจจัยหนึ่งที่อาจมีความสัมพันธ์กับกลุ่มอาการที่เกิดขึ้นกับผู้ปฏิบัติงานในอาคารสำนักงาน ตลอดจนระดับความพึงพอใจของผู้ปฏิบัติงานในอาคารต่อคุณภาพ

อากาศและสภาพแวดล้อมที่แตกต่างกันก็เป็นเหตุผลให้มีการปรับระบบการบริหารจัดการคุณภาพอากาศและสภาพแวดล้อมในอาคารสำนักงานเช่นกัน และผู้วิจัยก็ปฏิบัติงานในอาคารสำนักงานที่ศึกษาแห่งนี้ซึ่งสามารถให้ข้อมูลที่เป็นประโยชน์ต่อการศึกษาครั้งนี้ ดังนั้นการศึกษาวิจัยนี้จึงมีวัตถุประสงค์เพื่อหาข้อเท็จจริงในเรื่องดังกล่าว โดยการตรวจวัดคุณภาพอากาศและสภาพแวดล้อมในอาคารสำนักงาน การเก็บข้อมูลจากแบบสอบถามเพื่อสอบถามอาการที่เกี่ยวเนื่องกับคุณภาพอากาศและสภาพแวดล้อมในอาคารสำนักงานและความพึงพอใจต่อคุณภาพอากาศและสภาพแวดล้อม รวมทั้งการสำรวจการบริหารจัดการอากาศของอาคารโดยรวม เพื่อเป็นประโยชน์ในการแก้ไขและป้องกันปัจจัยใดๆที่อาจมีผลกระทบต่อสุขภาพของผู้ปฏิบัติงานในอาคารสำนักงานให้เหมาะสมต่อไป ดังนั้นทุกคนที่เข้าร่วมโครงการนี้จึงมีส่วนสำคัญในการเป็นอาสาสมัครของการศึกษาวิจัยในครั้งนี้

8. ระยะเวลาที่ต้องทำการทดลอง/ทดสอบในผู้ยินยอมตนให้ทำการวิจัย

เวลาที่ใช้ในการตอบแบบสอบถามของท่านประมาณ 5-10 นาที ทั้งนี้ขึ้นอยู่กับความสะดวกของท่าน สำหรับวลาที่ใช้ในการตรวจวัดคุณภาพอากาศส่วนใหญ่จะทำการเก็บตัวอย่างและอ่านค่าทันทียกเว้นการตรวจวัดฝุ่นจะทำการเก็บตัวอย่าง 5 ชั่วโมง

9. ประโยชน์ที่คาดว่าจะเกิดขึ้นทั้งต่อผู้ยินยอมตนให้ทำการวิจัย และต่อผู้อื่น

1. การจัดทำโครงการนี้เป็นการปรับปรุงสถานที่ทำงานให้มีคุณภาพอากาศและสภาพแวดล้อมเป็นไปตามเกณฑ์มาตรฐานและความพึงพอใจของผู้ที่ปฏิบัติงานในอาคารสำนักงาน ทั้งนี้เพื่อลดอาการป่วยที่เกี่ยวเนื่องจากการปฏิบัติงานในอาคารสำนักงาน ตลอดจนส่งผลให้ผู้ที่ปฏิบัติงานในอาคารสำนักงานมีสุขภาพอนามัยที่ดี การทำงานมีประสิทธิภาพมากขึ้น และไม่ส่งผลกระทบต่อครอบครัวหรือคนที่ท่านรักตลอดจนมีการส่งเสริมสุขภาพให้กับผู้ปฏิบัติงานในสำนักงานที่ศึกษาต่อไป
2. สำนักงานในอาคารประเภทเดียวกันอาจนำผลและแนวทางในการควบคุมไปประยุกต์ใช้
3. ทำให้ทราบและมั่นใจถึงความสัมพันธ์ระหว่างคุณภาพอากาศและสภาพแวดลัอม กับอาการและความพึงพอใจของคนทำงานในอาคารสำนักงาน ซึ่งอาจนำไปสู่การกำหนดข้อมูลพื้นฐานในการบริหารจัดการหรือคัดเลือกอาคารสำนักงานเพื่อความปลอดภัย (Healthy Building) ของผู้อาศัยต่อไป

10. ความเสี่ยง หรือ ความไม่สบายใดๆที่คาดว่าจะเกิดขึ้นกับผู้ยินยอมตนให้ทำการวิจัย ในระหว่างการเข้าร่วมการศึกษาวิจัย

ความเสี่ยงจากการเดินสะดุดหรือชนเครื่องมือตรวจวัดคุณภาพอากาศและสภาพแวดล้อมอาจจะเกิดขึ้นกับท่านให้ทำการวิจัยเช่น เครื่องมือเก็บตัวอย่างฝุ่นเป็นเครื่องมือที่ใช้ระยะเวลาในการเก็บ โดยผู้วิจัยจะติดตั้งเครื่องมือและวางไว้ในบริเวณพื้นที่ปฏิบัติงานทั้งนี้อาจมีเสียงรำคาญของปั๊มเก็บตัวอย่างอากาศต่อผู้ปฏิบัติงานและไม่สะดวกในการใช้พื้นที่ สำหรับเครื่องมือตรวจวัดอื่นๆ นั้นผู้วิจัยจะดำเนินการตรวจและอ่านค่าโดยทันที จึงไม่ทำให้เกิดความเสี่ยงหรือขัดขวางการทำงานของท่านให้ทำการวิจัย

ในการตอบแบบสอบถามผ่านทาง web surveyนั้น คำถามบางข้ออาจทำให้ท่านรู้สึกไม่สบายใจที่จะให้ข้อมูล แต่ผู้วิจัยยืนยันว่าจะรักษาความลับทั้งหมดตลอดการทำวิจัย และข้อมูลที่นำเสนอเป็นการนำเสนอข้อมูลในภาพรวม ซึ่งผู้วิจัยจะไม่ทำให้เกิดผลกระทบใดๆ ต่อท่าน และไม่มีการนำไปเปิดเผยต่อที่สาธารณะ การเปิดเผยจะเป็นข้อสรุปทางวิชาการเท่านั้น

สำหรับการตอบคำถามจากแบบสำรวจสภาพแวดล้อมของอาคารนั้น คำถามบางข้ออาจทำให้ท่านรู้สึกไม่สบายใจที่จะให้ข้อมูล แต่ผู้วิจัยยืนยันว่าจะรักษาความลับทั้งหมดตลอดการทำวิจัย และข้อมูลที่นำเสนอเป็นการนำเสนอข้อมูลในภาพรวม ซึ่งผู้วิจัยจะไม่ทำให้เกิดผลกระทบใดๆ ต่อท่าน และไม่มีการนำไปเปิดเผยต่อที่สาธารณะ การเปิดเผยจะเป็นข้อสรุปทางวิชาการเท่านั้น

11. มาตรการหรือวิธีการในการป้องกัน หรือลดความเสี่ยงหรือความไม่สบายใดๆ ที่อาจเกิดขึ้นในระหว่างการเข้าร่วมโครงการ

การตรวจวัดคุณภาพอากาศและสภาพแวดล้อมสำหรับเครื่องมือที่ต้องใช้ระยะเวลาในการเก็บตัวอย่างเช่น ฝุ่น อุณหภูมิ ผู้วิจัยจะติดป้ายชี้บ่งชื่อเครื่องมือ ข้อควรระวังและป้องกัน ระยะเวลาในการเก็บ ผู้รับผิดชอบ และเบอร์ติดต่อพร้อมกั้นบริเวณที่มีการติดตั้งเครื่องมือเพื่อความปลอดภัยในการเดินสะดุดหรือชน

สำหรับการตอบแบบสอบถามนั้นผู้วิจัยจะสื่อสารโดยสรุปของงานวิจัยต่อท่านตนในแต่ละชั้นที่เข้าร่วมศึกษาก่อนที่จะส่งแบบสอบถามผ่าน web survey หากผู้ยินยอมตนไม่เข้าใจสามารถสอบถามผู้วิจัยได้ตลอดระยะเวลาในการเข้าร่วมวิจัย ทั้งนี้ท่านสามารถตอบแบบสอบถามตามเวลาที่สะดวก

ทั้งนี้สำรวจสภาพแวดล้อมของอาคารก็เช่นกันผู้วิจัยจะขออนุญาตการขอข้อมูลก่อนสำรวจโดยอธิบายเอกสารชี้แจงการวิจัยแก่ท่านให้ทำการวิจัยกล่าวถึงขอบเขตและความเป็นมาของโครงการวิจัยตลอดจนวัตถุประสงค์ของการขอข้อมูลจากตัวแทนของอาคาร โดยสังเขป การอธิบายในแต่ละคำถามจะเป็นส่วนหนึ่งในการดำเนินการเก็บข้อมูล

12. การดูแลรักษาความลับของข้อมูลต่างๆ ของผู้ยินยอมตนให้ทำการวิจัย

ข้อมูลต่างๆที่เกี่ยวข้องกับท่าน ผู้วิจัยจะเก็บรักษาไว้ในเครื่องคอมพิวเตอร์ของผู้วิจัยซึ่งต้องใส่รหัสผ่านส่วนตัวของผู้วิจัยเท่านั้น ดังนั้นจะมีเพียงผู้วิจัยเท่านั้นที่ดูข้อมูลได้ และในการวิเคราะห์ข้อมูลจะใช้รหัสของบุคคลแทนชื่อจริง ทั้งนี้ข้อมูลจะทำลายเมื่องานวิจัยเสร็จสิ้นภายในสิ้นปี 2553

13. สิทธิผู้ยินยอมตนให้ทำการวิจัยจะถอนตัวออกจากโครงการวิจัยได้ทุกเมื่อ

ท่านจะได้อ่านหรือรับฟังรายละเอียดของการวิจัย หากมีข้อสงสัยใดๆ สามารถซักถามผู้วิจัยได้ โดยที่ผู้วิจัยจะไม่ปิดปังความจริงใดๆ การวิจัยครั้งนี้ท่านจะไม่ได้สิ่งของตอบแทนใดๆ ข้อมูลของจะเก็บรักษาเป็นความลับ และท่านมีสิทธิ์ที่จะถอนตัวจากการศึกษาครั้งนี้เมื่อใดก็ได้โดยไม่มีอะไรในด้านลบจากผู้วิจัยที่เกี่ยวข้องกับการศึกษาครั้งนี้ หรือท่านที่สมัครใจเข้าร่วมโครงการในตอนแรกและต่อมาขอยุติการเข้าร่วมโครงการ ท่านสามารถขอถอนตัวออกจากการศึกษาได้ตลอดเวลาเมื่อเกิดความไม่สบายใจในการตอบแบบสอบถามหรือการเข้าร่วมการทำวิจัย

14. ผู้รับผิดชอบที่ผู้ยินยอมตนให้ทำการวิจัยสามารถติดต่อได้โดยสะดวก กรณีมีเหตุจำเป็น หรือฉุกเฉิน

นางสาวพรธิดา ยืนสุข 99 ภาควิชาอาชีวอนามัยและความปลอดภัย คณะสาธารณสุขศาสตร์ มหาวิทยาลัยมหิดล เลขที่ 420/1 ถนนราชวิถี แขวงทุ่งพญาไท เขตราชเทวี กทม. 10400

โทร 0 2644 4069-70

โทรศัพท์ 08-9440 1319

E-mail address: phornthida.y@hotmail.com

หนังสือยินยอมตนให้ทำการวิจัย

(Informed Consent Form)

โครงการวิจัยเรื่อง ความสัมพันธ์ระหว่างคุณภาพอากาศและสภาพแวดล้อม กับอาการและความพึงพอใจของคนทำงานในอาคารสูง

วันที่ให้คำยินยอม วันที่ ……….. เดือน………….. พ.ศ. ………….

ข้าพเจ้า (นาย/นาง/นางสาว) ……..……….…………………………………………ขอทำหนังสือนี้ไว้ต่อหัวหน้าโครงการเพื่อเป็นหลักฐานแสดงว่า

ข้อ 1. ก่อนลงนามในใบยินยอมตนให้ทำการวิจัยนี้ ข้าพเจ้าได้รับการอธิบายจากผู้วิจัยให้ทราบถึงวัตถุประสงค์ของการวิจัย วิธีการวิจัย อันตราย หรือความรำคาญและความรู้สึกอึดอัดใจที่อาจเกิดขึ้นจากการวิจัย รวมทั้งประโยชน์ที่จะเกิดขึ้นจากการวิจัยอย่างละเอียด และมีความเข้าใจดีแล้ว

ข้อ 2. ผู้วิจัยรับรองว่าจะตอบคำถามต่างๆ ที่ข้าพเจ้าสงสัยด้วยความเต็มใจ ไม่ปิดบัง ซ่อนเร้น จนข้าพเจ้าพอใจ

ข้อ 3. ข้าพเจ้าเข้าร่วมโครงการวิจัยนี้โดยสมัครใจ และข้าพเจ้ามีสิทธิที่จะบอกเลิกการเข้าร่วมในโครงการวิจัยนี้เมื่อใดก็ได้ และการบอกเลิกการเข้าร่วมวิจัยนี้จะไม่มีผลต่อการทำงานของข้าพเจ้าต่อไป

ข้อ 4. ผู้วิจัยรับรองว่า จะเก็บข้อมูลเฉพาะเกี่ยวกับตัวข้าพเจ้าเป็นความลับ และจะเปิดเผยได้เฉพาะในรูปที่เป็นสรุปผลการวิจัย การเปิดเผยข้อมูลเกี่ยวกับตัวข้าพเจ้าต่อหน่วยงานต่างๆที่เกี่ยวข้อง กระทำได้เฉพาะกรณีจำเป็นด้วยเหตุผลทางวิชาการเท่านั้น

ข้อ 5. ผู้วิจัยรับรองว่า หากมีข้อมูลเพิ่มเติมที่ส่งผลกระทบต่อการวิจัย ข้าพเจ้าจะได้รับการแจ้งให้ทราบทันทีโดยไม่ปิดบัง ซ่อนเร้น

ข้าพเจ้าได้อ่านข้อความข้างต้นแล้วมีความเข้าใจดีทุกประการ และได้ลงนามในใบยินยอมนี้ด้วยความเต็มใจ

ลงชื่อ ……………………………………….…… ผู้ยินยอม

(……………………………………………..)

ลงชื่อ ……………………………..…………… พยาน

(……….…………………………………….)

ลงชื่อ ……………………………..…………… พยาน

(……….…………………………………….)

APPENDIX D

INSTRUMENT PICTURE

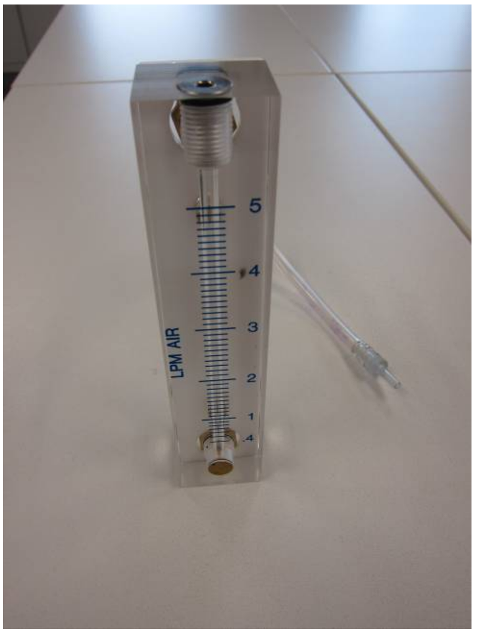
MiniRae 2000: TVOCs measurement

Formaldehyde Meter Model Z-300

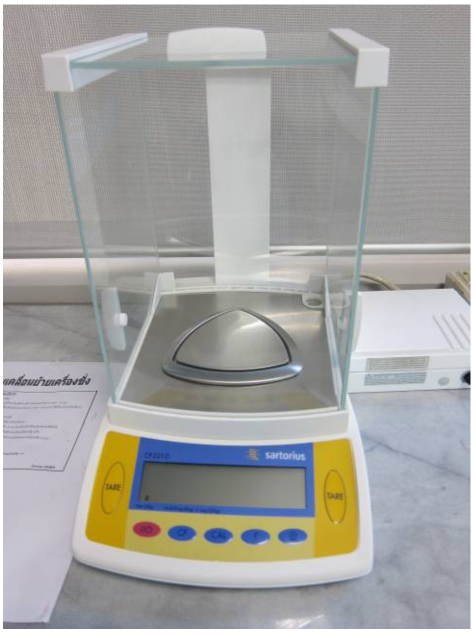
Ozone Meter Model Z-1200

TSI IAQ Meter Model Q-Trak Plus

Samplings pump AirCheck 52 and filter holder



Rotameter SKC



Micro Balance

Lux meter

Sound level meter

Anemometer RS232

APPENDIX E
QUESTIONNAIRE FORM

Occupant Symptoms and Satisfactions with Indoor Air Quality and Indoor Environmental Quality Questionnaire

This questionnaire is part of the research project: **the relationship between Indoor Air Quality and Indoor Environmental Quality with Occupant Symptoms and Satisfactions**, the objective is to promote occupants' health who regularly working in office building. These studies will measure the indoor air quality and indoor environmental quality by the industrial hygiene instrument, occupant symptoms and satisfactions data will be collected by using this questionnaire.

The real answer will be the usefulness for all office building occupants. Thank you very much for your kind corporation.

Occupant Symptoms and Satisfactions with Indoor Air Quality and Indoor Environmental Quality Questionnaire **in high building**

Date: ………/……../…….

Part I Demographic Data

Please answer the following questions by filling ✓ in the blank or checking the correct data

1. Gender ( ) Male ( ) Female

2. Age …………years

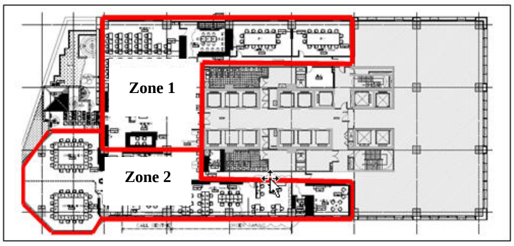
3. Education ( ) high school ( ) diploma

( ) bachelor degree ( ) master degree & higher

4. Race ( ) Thai ( ) other please specify……….

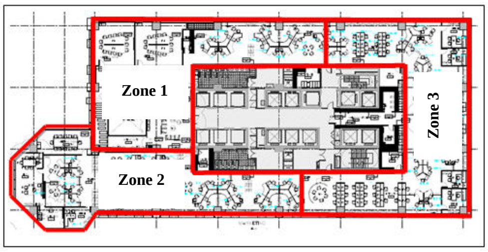
5. Area and zone where you worked

7th floor



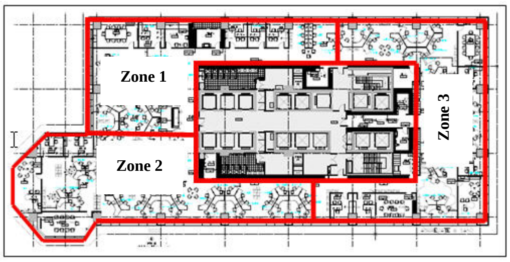
( ) Zone 1 ( ) Zone 2

8th floor



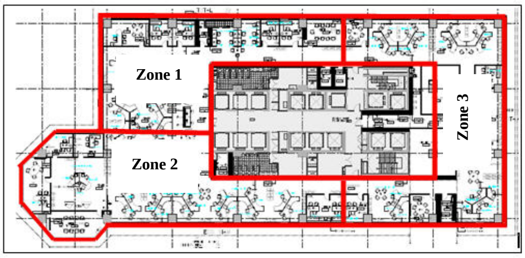
( ) Zone 1 ( ) Zone 2 ( ) Zone 3

9th floor



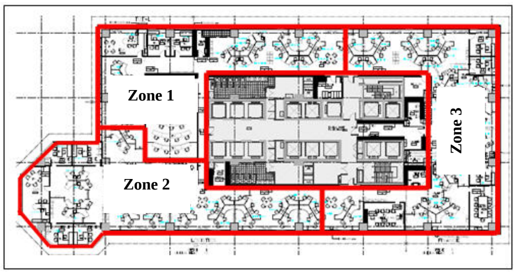
( ) Zone 1 ( ) Zone 2 ( ) Zone 3

10th floor



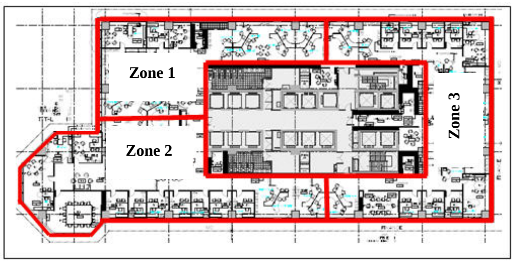
( ) Zone 1 ( ) Zone 2 ( ) Zone 3

11th floor



( ) Zone 1 ( ) Zone 2 ( ) Zone 3

12th floor



( ) Zone 1 ( ) Zone 2 ( ) Zone 3

6. How many hours per day do you spend in this office building? ....
and other place…………….., please specify location…………………………………

Part II A history of Occupant health in the last month

1. Have you had any of the following diseases?

( ) allergies ( ) asthma
( ) sinusitis ( ) cold/flu
( ) migraine ( ) skin allergies/dermatitis
( ) tuberculosis ( ) eye allergies
( ) dust allergies ( ) not any

How do you manage all illness?

( ) see the doctor ( ) see the company nurse
( ) see the pharmaceutical ( ) No any.

2. Do you wear contact lenses? ( ) No
( ) Yes, how often?( ) daily ( ) periodically

3. Do you smoke? ( ) No
( ) Yes, how many cigarettes per day? ………………
where do you smoke ( ) 7th floor terrace ( ) Ground floor

Part III Occupant symptoms which related to indoor air quality and indoor environmental quality issues in the last month

1. Checking symptoms you have experienced in this office last few months (if nothing please pass to Part IV) (select more than one)

( ) headache ( ) eye irritation
( ) nose irritation ( ) throat irritation
( ) cold symptoms ( ) shortness of breath, chest pains
( ) dizziness or faintness ( ) dry skin, itchy skin, itchy skin rash
( ) exhaust, drowsy ( ) back pain
( ) dry mouth ( ) fever
( ) vomit ( ) Not any

2. Symptoms in No.1 pattern

Symptoms occur is ( ) intermittently ( ) continually ( ) once

2.1 symptoms frequency……………. (times/day, times/week, times/month)

2.2 how long of the symptoms occurred?

( ) several minutes ( ) several hours

( ) all day ( ) all time in the office

2.3 symptoms form consistency occurred?

( ) Yes ( ) No please pass to No.3

2.4 are there a specific day (s) of the week that you experience the problem? (Select more than one)

( ) Mon ( ) Tue ( ) Wed ( ) Thu ( ) Fri ( ) Sat ( ) Sun

2.5 What time of day do you experience the problem?

( ) Morning ( ) Afternoon ( ) Evening

( ) all the time ( ) Unpredictability

3. In what circumstances are you experienced the following symptoms, seriously and frequently?

3.1 In door	( ) cold	( ) hot
	( ) hot and cold	( ) quiet weather
3.2 Out door	( ) rainy and stormy	( ) windy
	( ) quiet or windy	( ) quiet weather

4. Prior the symptoms occurred, do you worked specifically before?

( ) No ( ) Yes, please specify……………………………….

5. While symptoms occurred, do you worked specifically location?

( ) No ( )Yes, please specify……..………………..

6. Do you have an idea as to what is the cause of symptoms in your workplace? ………………………………………………………………………….

Part IV Indoor Air Quality and Indoor Environmental Quality with Occupant Satisfactions

Please checking ✓ from the following scale (5 scale) that best describes condition in your working area

No	Topics	Satisfaction Level				
		Slightly	Low	Medium	High	Very high
		1	2	3	4	5
Indoor Air Quality Satisfaction						
1	Do you satisfy dust in the office?					
2	Do you satisfy odor in the office?					
3	Do you satisfy air movement in the office?					
Indoor Environmental Quality Satisfaction						
4	Do you satisfy comfortable temperature in the office?					
5	Do you satisfy light in the office?					
6	Do you satisfy sound in the office?					

QUESTIONNAIRE FORM

แบบสอบถามข้อมูลด้านอาการและความพึงพอใจต่อคุณภาพอากาศและสภาพแวดล้อมของคนทำงานในอาคารสูง

แบบสอบถามนี้ เป็นส่วนหนึ่งของการโครงการวิจัยเรื่อง ความสัมพันธ์ระหว่างคุณภาพอากาศและสภาพแวดล้อม กับอาการและความพึงพอใจของคนทำงานในอาคารสูง เพื่อส่งเสริมสุขภาพของผู้ปฏิบัติงานในสำนักงานอาคารสูง โดยการศึกษาครั้งนี้จะดำเนินการตรวจวัดคุณภาพอากาศและสภาพแวดล้อมด้วยเครื่องมือทางสุขศาสตร์อุตสาหกรรม และสอบถามข้อมูลด้านสุขภาพที่มีอาการเกี่ยวเนื่องกับคุณภาพอากาศและสภาพแวดล้อมในอาคาร และความพึงพอใจต่อคุณภาพอากาศและสภาพแวดล้อมของผู้ที่อาศัยในอาคารดังกล่าว

ขอขอบคุณท่านเป็นอย่างสูงในการกรอกแบบสอบถามนี้

แบบสอบถามข้อมูลด้านอาการและความพึงพอใจต่อคุณภาพอากาศและสภาพแวดล้อมในอาคารสูง

วัน/เดือน/ปี ที่ตอบแบบสอบถาม…………………

ส่วนที่ 1 ข้อมูลทั่วไปของผู้ตอบแบบสอบถาม

คำชี้แจง โปรดทำเครื่องหมาย ✓ ลงในช่อง ( ) และ/หรือเติมข้อความลงในช่องว่าง

1. เพศ ( ) ชาย ( ) หญิง

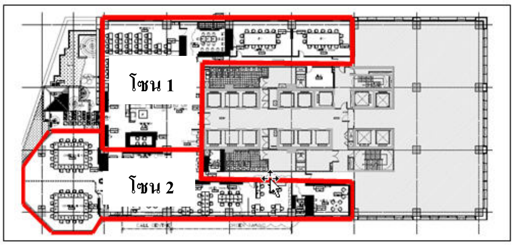
2. อายุ …………… ปี

3. ระดับการศึกษา ( ) มัธยมศึกษา ( ) อนุปริญญา
( ) ปริญญาตรี ( ) สูงกว่าปริญญาตรี

4. เชื้อชาติ ( ) ไทย ( ) ต่างชาติ โปรดระบุ……….... ……………

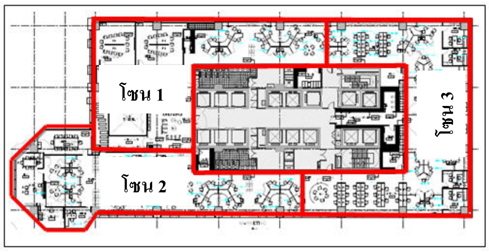
5. ท่านทำงานอยู่ที่ชั้นใด และโซนใด

ชั้น 7



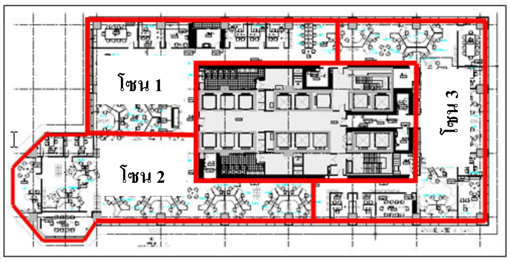
( ) โซน 1 ( ) โซน 2

ชั้น 8



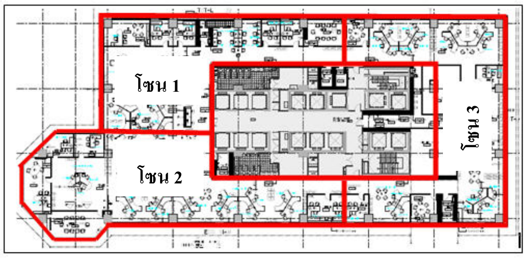
( ) โซน 1 ( ) โซน 2 ( ) โซน 3

ชั้น 9



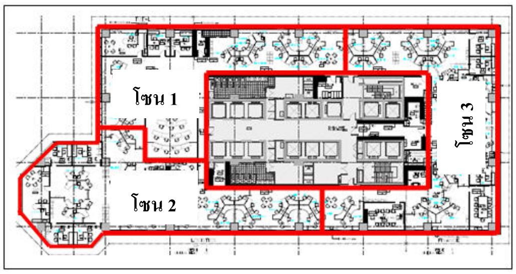
( ) โซน 1 ( ) โซน 2 ( ) โซน 3

ชั้น 10



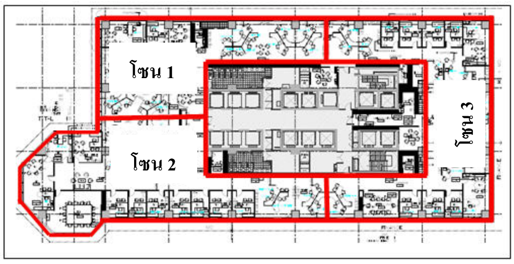
( ) โซน 1 ( ) โซน 2 ( ) โซน 3

ชั้น 11



( ) โซน 1 ( ) โซน 2 ( ) โซน 3

ชั้น 12



( ) โซน 1 ( ) โซน 2 ( ) โซน 3

6. ในระหว่างวันทำงานท่านใช้เวลาอยู่ในห้องทำงานหรือสำนักงาน..........ชม./วัน

ที่อื่น............ชม./วัน ระบุสถานที่...

ส่วนที่ 2 ข้อมูลเกี่ยวกับอาการและประวัติการเจ็บป่วยในรอบ 1 เดือนที่ผ่านมา

1. ท่านมีปัญหาสุขภาพต่อไปนี้หรือไม่ (ตอบได้มากกว่า 1 ข้อ)

( ) ภูมิแพ้	( ) โรคหอบหืด
( ) ไซนัส (โพรงจมูกอักเสบ)	( ) ไข้หวัด
( ) ไมเกรน	( ) โรคผิวหนัง
( ) โรควัณโรค	( ) ระคายเคืองตา
( ) แพ้ฝุ่นละออง	( ) ไม่เคยมีโรคประจำตัว

และท่านจัดการกับปัญหาเหล่านี้อย่างไร

( ) ไปพบแพทย์ ( ) ไปพบพยาบาลของบริษัทฯ ( ) ซื้อยาใช้เอง

2. ท่านใส่คอนแทคเลนซ์หรือไม่ ( ) ไม่ใส่

( ) ใส่

ความถี่ในการใส่คอนแทคเลนส์ ( ) ทุกวัน ( ) ใส่บ้าง ไม่ใส่บ้าง

3. ท่านสูบบุหรี่หรือไม่ ( ) สูบ ปริมาณที่สูบ/วัน………..มวน

ท่านสูบบุหรี่ที่ไหน(ตอบได้มากกว่า 1 ข้อ)

( ) สวนหย่อมชั้น 7

( ) จุดสูบบุหรี่ชั้นล่าง

( ) อื่นๆ ระบุ……………………

( ) ไม่สูบ

ส่วนที่ 3 ข้อมูลอาการที่เกี่ยวเนื่องกับคุณภาพอากาศและสภาพแวดล้อมในรอบ 1 เดือนที่ผ่านมา

1. ท่านมีอาการต่อไปนี้หรือไม่ (เลือกได้มากกว่าหนึ่งอาการ) ถ้าไม่มีข้ามไปตอบส่วนที่ 4

( ) ปวดศีรษะ ( ) ระคายเคืองตา แสบตา

( ) คัดจมูก ระคายเคืองจมูก ( ) ระคายเคืองคอ คอแห้ง

( ) มีอาการเหมือนเป็นหวัด ( ) หายใจลำบาก หายใจหอบ แน่นหน้าอก

( ) วิงเวียน เป็นลม ( ) ผิวหนังแห้ง คันผิวหนัง ผิวหนังเป็นผื่นคัน

( ) เหนื่อยล้า เซื่องซึม ง่วงนอน ( ) ปวดเมื่อยเนื้อตัว ปวดหลัง

( ) ปากแห้ง ( ) เป็นไข้

( ) คลื่นไส้ ( ) อื่นๆ ระบุ……………………………….

2. ลักษณะการเกิดอาการดังกล่าวในข้อ 1

( ) เป็นๆ หายๆ ( ) เป็นอย่างต่อเนื่อง ( ) เป็นครั้งเดียว

2.1 ความถี่ของอาการ…………………………………. (ครั้ง/วัน, สัปดาห์, เดือน)

2.2 อาการที่เกิดขึ้นจะเป็นอยู่นานแค่ไหน

( ) หลายนาที ( ) หลายชั่วโมง

( ) ทั้งวัน ( ) ตลอดเวลา

2.3 เวลาที่เกิดอาการดังกล่าวมีรูปแบบที่แน่นอนหรือไม่

( ) มี ( ) ไม่มี (ข้ามไปตอบข้อ 3)

2.4 วันไหนของสัปดาห์ที่มีอาการปรากฏ (ตอบได้มากกว่า 1 ข้อ)

( ) จ ( ) อ ( ) พ ( ) พฤ ( ) ศ ( ) ส ( ) อ

2.5 เวลาไหนของวันที่มีอาการปรากฏ

( ) เช้า ( ) บ่าย ( ) เย็น ( ) ตลอดเวลา ( ) ไม่แน่นอน

3. สภาพอากาศอย่างไร ที่มักจะทำให้ท่านมีอาการปรากฏบ่อยที่สุด หรือรุนแรงที่สุด (ตอบได้มากกว่า 1 ข้อ)

3.1 ภายในอาคาร ( ) อากาศหนาว ( ) อากาศร้อน

( ) เดี๋ยวร้อน เดี๋ยวหนาว ( ) อากาศนิ่ง

3.2 ภายนอกอาคาร ( ) ฝนตก มีพายุ ( ) มีลมพัด

( ) นิ่งสงบ หรือมีลมโชยบ่อย ( ) อากาศนิ่ง

4. ก่อนมีอาการท่านได้ทำงานอย่างใดอย่างหนึ่งเฉพาะหรือไม่

( ) ไม่ ( ) ทำ ระบุงานที่ทำ…………………………………….

5. ท่านมักจะมีอาการดังกล่าวเมื่อท่านอยู่ในบริเวณใดบริเวณหนึ่งโดยเฉพาะหรือไม่

( ) ไม่ ( ) ใช่ ระบุสถานที่……………………………………..

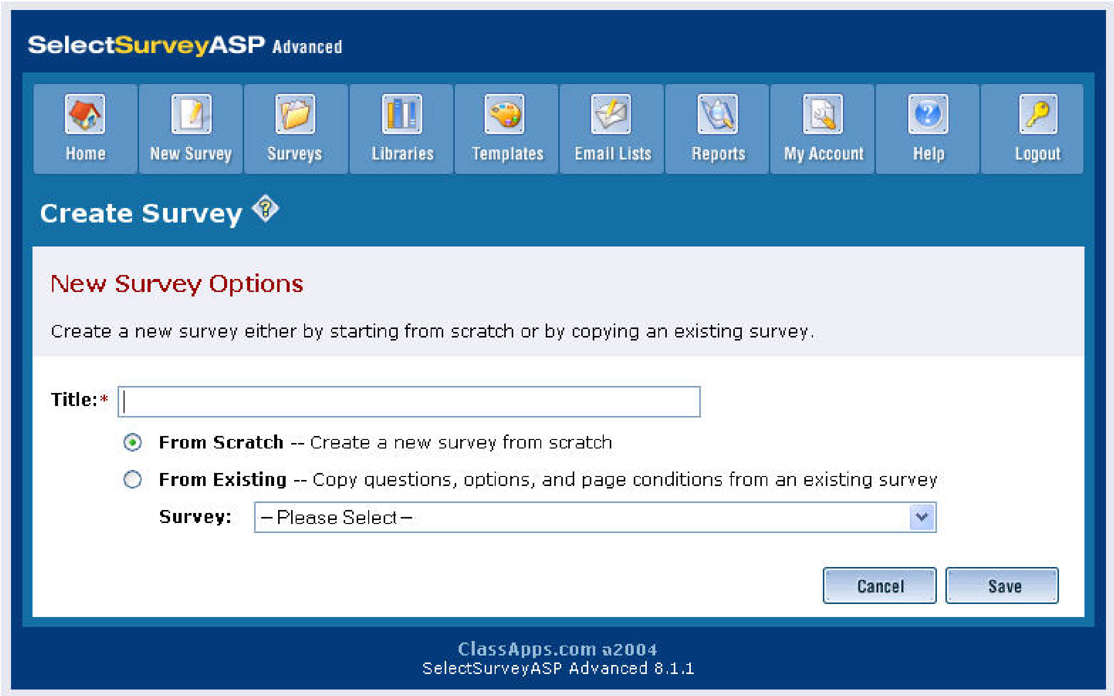
6. ท่านคิดว่าอะไรทำให้ท่านมีอาการดังกล่าว……………………………………………………….

ส่วนที่ 4 ข้อมูลความพึงพอใจของผู้ที่อาศัยในอาคารที่มีต่อคุณภาพอากาศและสภาพแวดล้อมในอาคารสูง

แบบสอบถาม ใน ส่วนที่ 4 นี้ เป็นแบบสอบถามที่ต้องการทราบความความพึงพอใจต่อสภาพอากาศและสภาพแวดล้อมในอาคารของผู้ที่ปฏิบัติงานภายในอาคารคอลัมน์ชั้น 7-12 ซึ่งมีทั้งหมด 6 ข้อ ขอให้ผู้ตอบแบบสอบถาม อ่านข้อความเหล่านี้ทีละข้อ แล้วพิจารณาระดับความพึงพอใจของท่านตามระดับที่กำหนดไว้ข้างล่างนี้ โดยให้ทำเครื่องหมาย ✓ ลงในช่องที่ต้องการหลังข้อคำถาม ซึ่งกำหนดไว้ 5 ระดับ

ข้อที่	ข้อความ	ระดับความพึงพอใจ				
		มากที่สุด	มาก	ปานกลาง	น้อย	น้อยที่สุด
		5	4	3	2	1
ความพึงพอใจต่อคุณภาพอากาศ						
1	ท่านรู้สึกพึงพอใจกับปริมาณฝุ่นที่มีในสำนักงานหรือไม่					
2	ท่านรู้สึกพึงพอใจกับกลิ่นหรือไม่					
3	ท่านรู้สึกพึงพอใจกับการไหลเวียนอากาศหรือไม่					
ความพึงพอใจต่อสภาพแวดล้อม						
4	ท่านรู้สึกพึงพอใจกับอุณหภูมิหรือไม่					
5	ท่านรู้สึกพึงพอใจกับแสงสว่างหรือไม่					
6	ท่านรู้สึกพึงพอใจกับเสียงหรือไม่					

Web survey


SelectSurveyASP Advanced
Home
New Survey
Surveys
Libraries
Templates
Email Lists
Reports
My Account
Help
Logout
Create Survey
New Survey Options
Create a new survey either by starting from scratch or by copying an existing survey.
Title:*
From Scratch -- Create a new survey from scratch
From Existing -- Copy questions, options, and page conditions from an existing survey
Survey:
-- Please Select --
Cancel
Save
ClassApps.com ©2004
SelectSurveyASP Advanced 8.1.1

APPENDIX F
THE SURVEY OF ENVIRONMENT BUILDING FORM

แบบสำรวจสภาพแวดล้อมของอาคาร

ส่วนที่ 1 สำหรับอาคาร

1. ข้อมูลทั่วไปของอาคาร

ชื่อ…………………………………………………………………………………………………

ที่อยู่ ………………………………………………………………………………………………

โทรศัพท์ …………………………………………… โทรสาร ……………………………

ชื่อผู้ให้ข้อมูล………………………………………. ตำแหน่ง……………………………

ปีที่สร้าง……………………ปีที่เปิดบริการ……………… จำนวนชั้น……………ชั้น

ข้อมูลของชั้นที่เปิดบริการ

ชั้นที่………..บริษัท…………………………………………………จำนวนพนักงาน………คน

จำนวนกะทำงาน………กะ ช่วงเวลาการทำงาน…………………….

ชั้นที่………..บริษัท…………………………………………………จำนวนพนักงาน………คน

จำนวนกะทำงาน………กะ ช่วงเวลาการทำงาน…………………….

เป็นต้น

2. ข้อมูลทั่วไปของสถานที่

2.1 บริเวณอาคารกว้าง…………..เมตร ยาว…………..เมตร พื้นที่ทั้งหมด………………ตร.ม.

2.2 ตัวอาคารกว้าง……….เมตร ยาว………..เมตร สูง…………..เมตร พื้นที่ทั้งหมด………ตร.ม.

ลักษณะอาคาร

( ) เอกเทศ สูง………… ชั้น

( ) ใช้อาคารร่วมกับกิจการอื่น สูง………… ชั้น ประกอบกิจการชั้นที่ ………………………..

2.3 การรักษาความสะอาด ความเป็นระเบียบเรียบร้อยบริเวณโดยรอบสถานประกอบการ

( ) ดี ( ) ไม่ดี

2.4 สถานที่จอดรถ ( ) ไม่มี

( ) มี ( ) เป็นเอกเทศ สูง……….. ชั้น ความจุ……………คัน

( ) ลานจอดรถ ความจุ…………….คัน

( ) อยู่ในอาคารประกอบการ ชั้นที่ ……….. ความจุ……….คัน

3. ลักษณะภายในอาคารและอุปกรณ์

3.1 โครงสร้างอาคาร

1) พื้นทำด้วย……………………………….. สภาพ ( ) ดี ( ) ไม่ดี

2) ฝาผนังทำด้วย………………...…………..สภาพ ( ) ดี ( ) ไม่ดี

3) เพดานทำด้วย…………………………...สภาพ ( ) ดี ( ) ไม่ดี

4) หลังคาทำด้วย…………………………...สภาพ ( ) ดี ( ) ไม่ดี

5) บริเวณทางเดินกว้าง………..……..เมตร สภาพ ( ) ดี ( ) ไม่ดี

6) บันไดขึ้นลง………….ทาง กว้าง………..เมตร สภาพ ( ) ดี ( ) ไม่ดี

3.2 กรณีมีการประกอบกิจการอื่น เช่น ร้านอาหาร ร้านเสริมสวย สถานออกกำลังกาย ธนาคาร ได้มีการกั้นบริเวณกิจการเหล่านั้นเป็นสัดส่วน

( ) ไม่กั้น ( ) กั้นเป็นสัดส่วน

( ) ไม่มีการประกอบกิจการอื่นๆ

3.3 โครงสร้างและสภาพทั่วไปในสำนักงานแต่ละชั้น

1) พื้นทำด้วย……………………………….. สภาพ ( ) ดี ( ) ไม่ดี

2) ฝาผนังทำด้วย………………...…………..สภาพ ( ) ดี ( ) ไม่ดี

3) เพดานทำด้วย…………………………...สภาพ ( ) ดี ( ) ไม่ดี

4. การระบายอากาศและระบบทำความเย็น

4.1 ระบบทำความเย็น ประเภทของระบบทำความเย็น

1) ( ) แยกแต่ละชั้น

ความถี่ในการทำความสะอาดเครื่องทำความเย็น……………………………….

2) ( ) ระบบรวม

ชนิดของอุปกรณ์ทำความเย็น…………………………………………………...

จุดที่ดึงอากาศเข้าอาคาร……………………………………………………………

อัตราการไหลของอากาศจากภายนอก (%OA) ……………………………………

จุดระบายอากาศออกจากอาคาร…………………………………………………

จุดระบายอากาศออกจากห้อง……………………………………………………..

การกระจายตัวของอากาศ ( ) ดี ( ) ไม่ดี

อุปกรณ์ทำความสะอาดอากาศ…………………………………………………….

หอผึ่งเย็น (cooling tower) ( ) มี ( ) ไม่มี

กำหนดการซ่อมบำรุงระบบ (ขอดูเอกสาร) ……………………………………….

3) มีการตรวจน้ำในระบบ

น้ำขังในถาดรองน้ำที่ควบแน่นในระบบ ( ) ไม่มี ( ) มี

ตรวจหาปริมาณจุลชีพ ( ) ไม่ตรวจ ( ) ตรวจ (ขอดูผล)

5. นโยบายเกี่ยวกับการสูบบุหรี่ ( ) มี ( ) ไม่มี

6. การทำความสะอาด

6.1 ความถี่ในการทำความสะอาด

ห้องน้ำ ……….. วัน/ครั้ง

โถงลิฟท์ ……….. วัน/ครั้ง

ในลิฟท์ ……….. วัน/ครั้ง

พื้นทั่วไป ……….. วัน/ครั้ง

กระจก ……….. วัน/ครั้ง

6.2 อุปกรณ์ทำความสะอาด……………………………………………………………………

6.3 สารทำความสะอาด 1)……………………………………………………

2) ……………………………………………………

3) ……………………………………………………

4) ……………………………………………………

APPENDIX G
THE SURVEY OF OFFICE BUIDLING CONTAMINANT SOURCES FORM

แบบสำรวจแหล่งของสารปนเปื้อนภายในและภายนอกอาคาร

ผู้สำรวจ:..		**วันที่:............................**
ชั้น/โซน	**แหล่งสารปนเปื้อน**	**สารปนเปื้อน**

APPENDIX H

THE MEASUREMENT LAYOUT

Respirable particulates

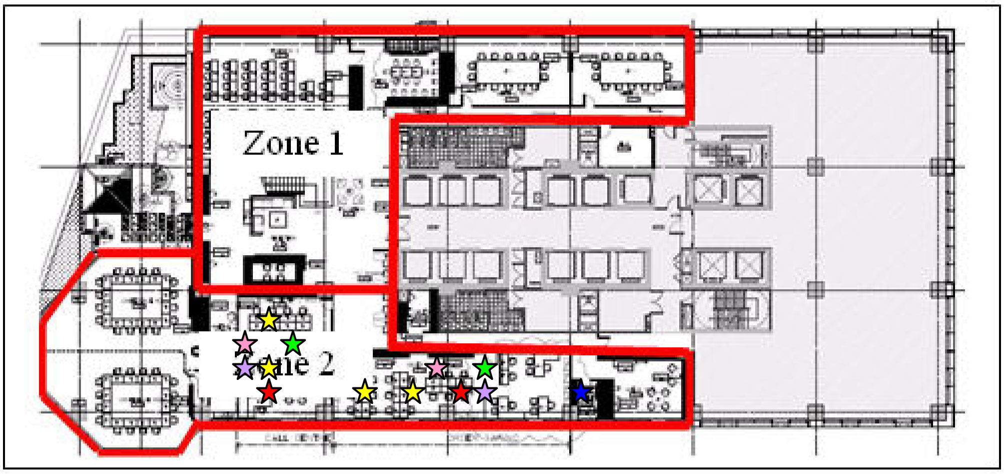
TVOCs/formaldehyde

Ozone/TVOCs

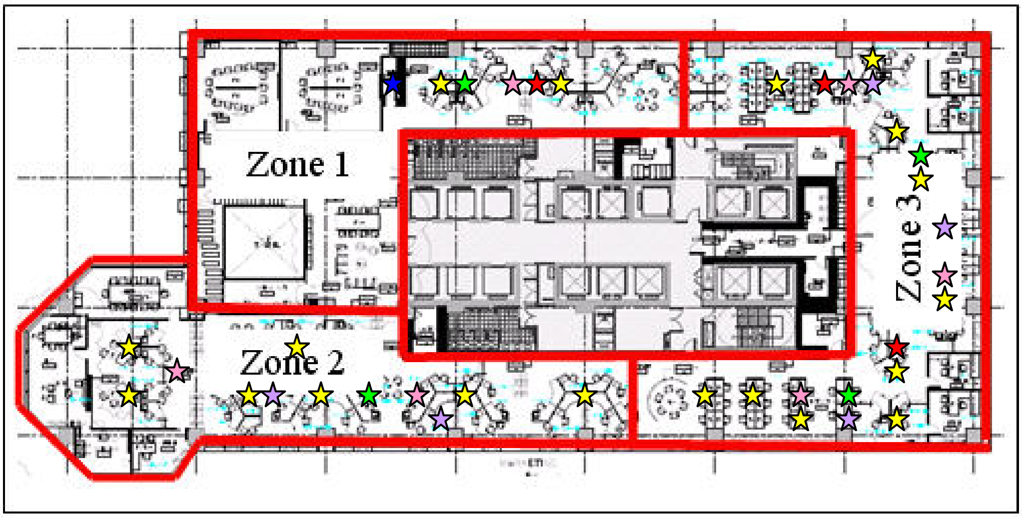
Carbon dioxide/temperature/relative humidity

Light

Sound

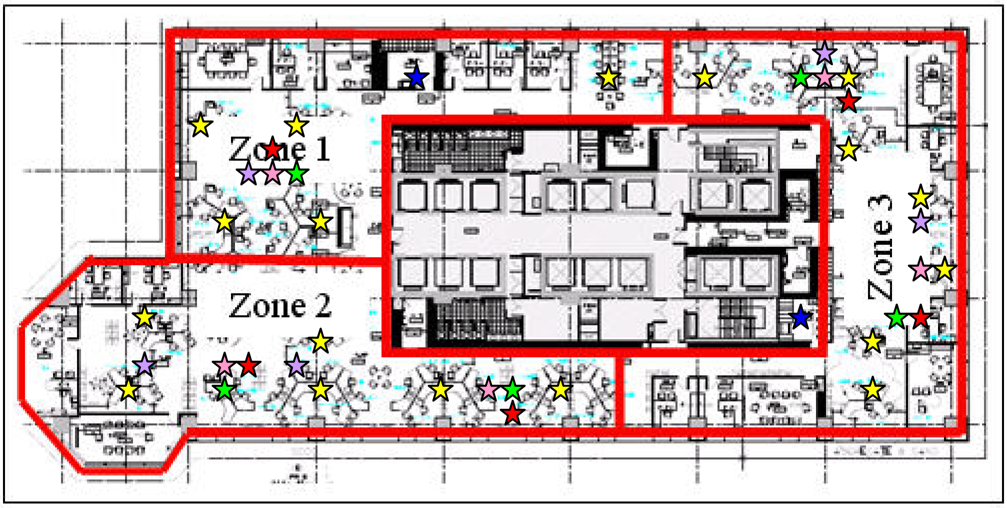


7th floor

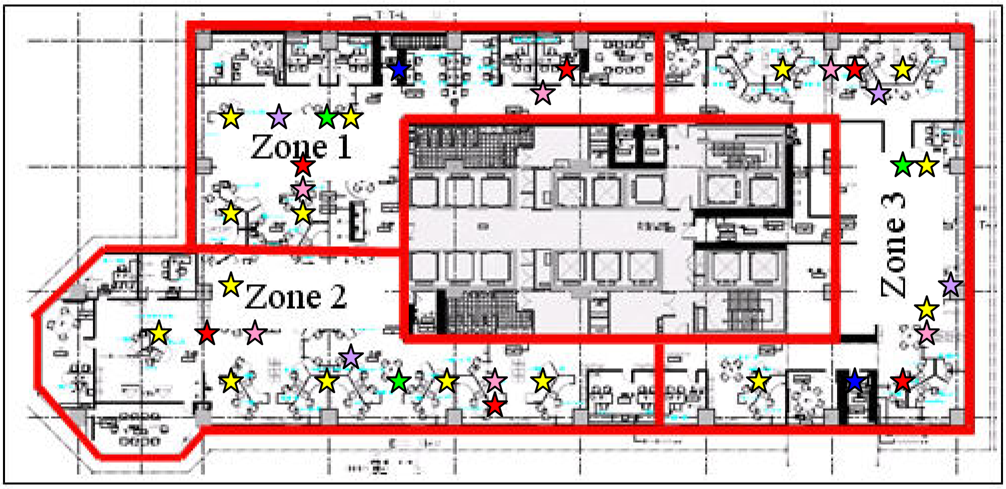


8th floor

THE MEASUREMENT LAYOUT

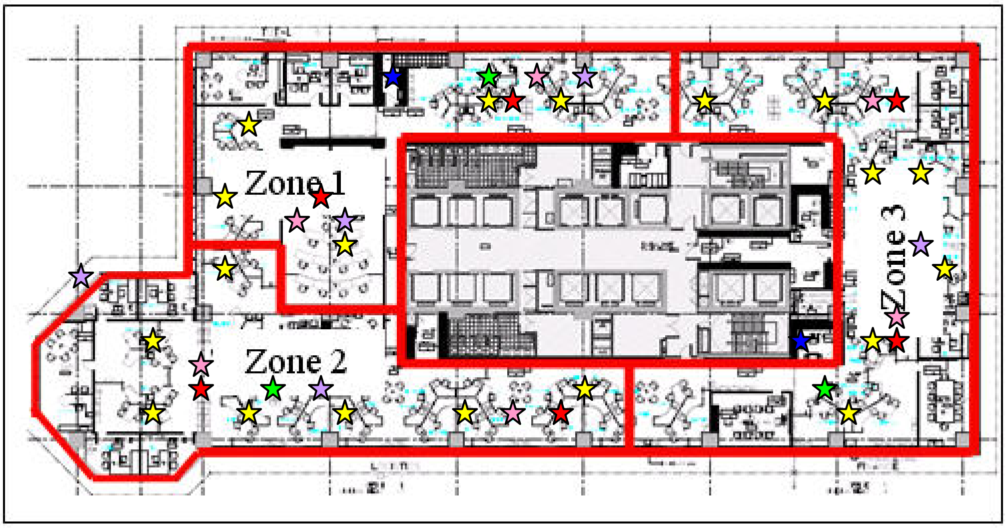


9th floor

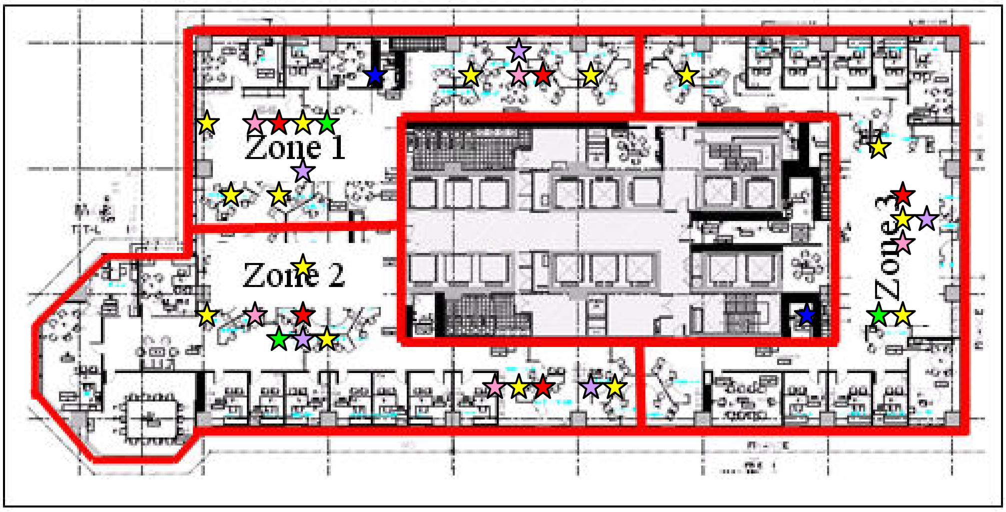


10th floor

THE MEASUREMENT LAYOUT



11th floor



12th floor

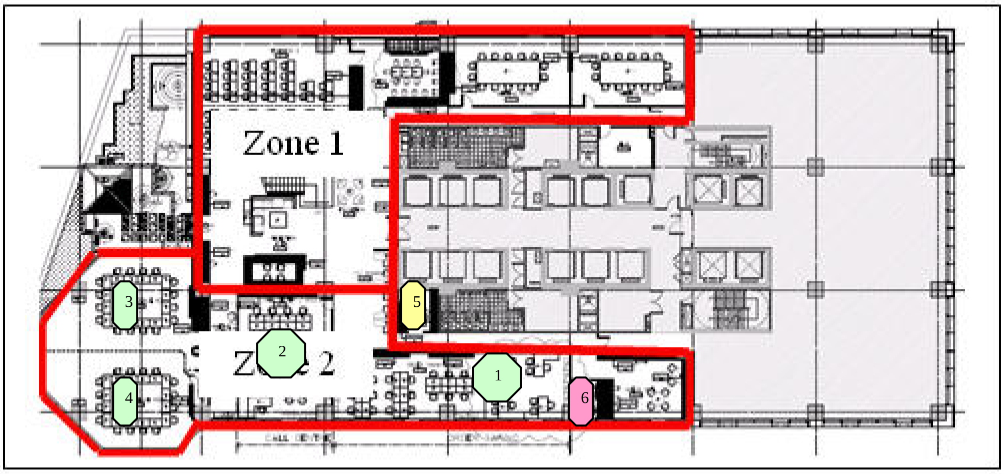
APPENDIX I
THE CALCULATION OF VENTILATION RATE

Floor	Zone	%OA	Q (cfm)	Fresh air (cfm)	# persons	Ventilation rate*
7	2	22.80	526.96	120.13	38	3.16
8	1	30.67	441.65	135.44	13	10.42
	2	34.90	1,739.57	607.14	40	15.18
	3	38.89	3,256.11	1,266.27	40	31.66
9	1	19.60	1,573.00	308.28	19	16.23
	2	23.87	2,257.76	538.99	32	16.84
	3	21.16	2,684.65	568.18	45	12.63
10	1	41.08	1,739.57	714.63	32	22.33
	2	30.31	2,574.55	780.44	24	32.52
	3	32.61	2,788.25	909.21	32	28.41
11	1	20.67	1,581.25	326.89	22	14.86
	2	22.49	3,547.91	797.76	32	24.93
	3	20.71	4,466.97	925.30	40	23.13
12	1	26.90	2,105.90	566.46	26	21.79
	2	33.74	2,591.82	874.44	27	32.39
	3	35.39	3,469.31	1,227.90	27	45.48

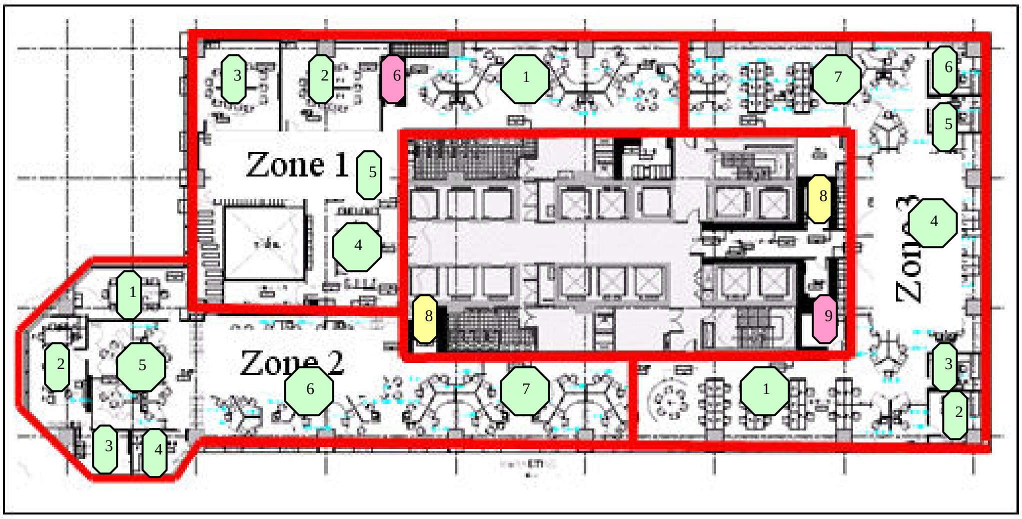
* (76)

APPENDIX J

THE VENTILATION MEASURMENT LAYOUT

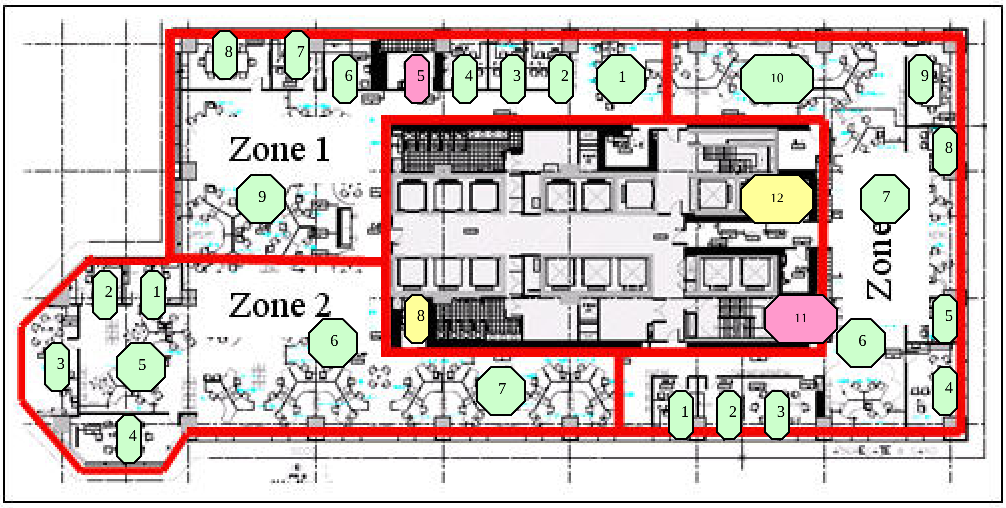


7th floor

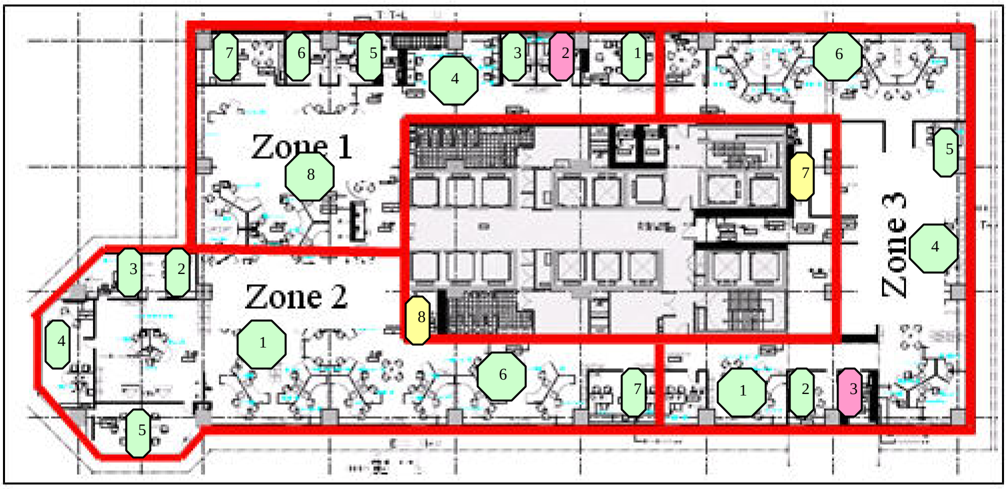


8th floor

THE VENTILATION MEASURMENT LAYOUT

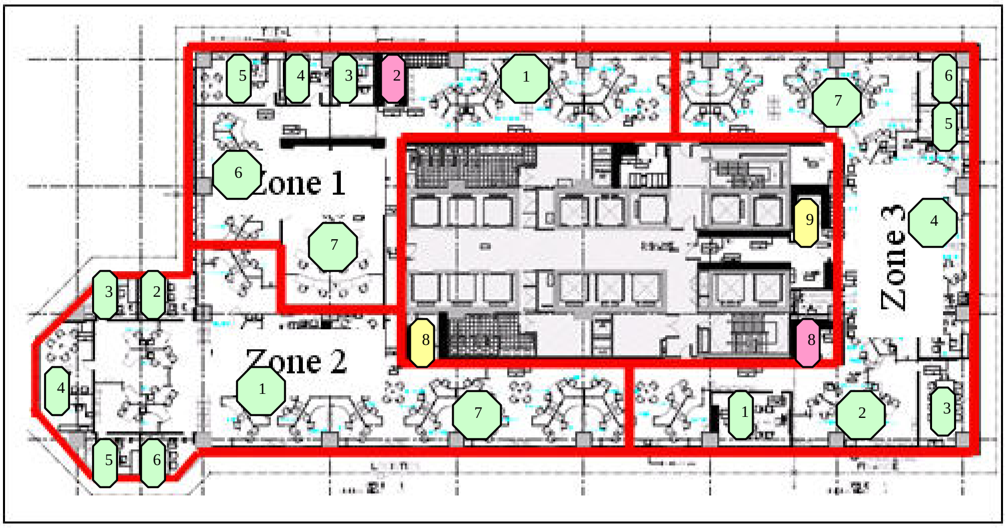


9th floor

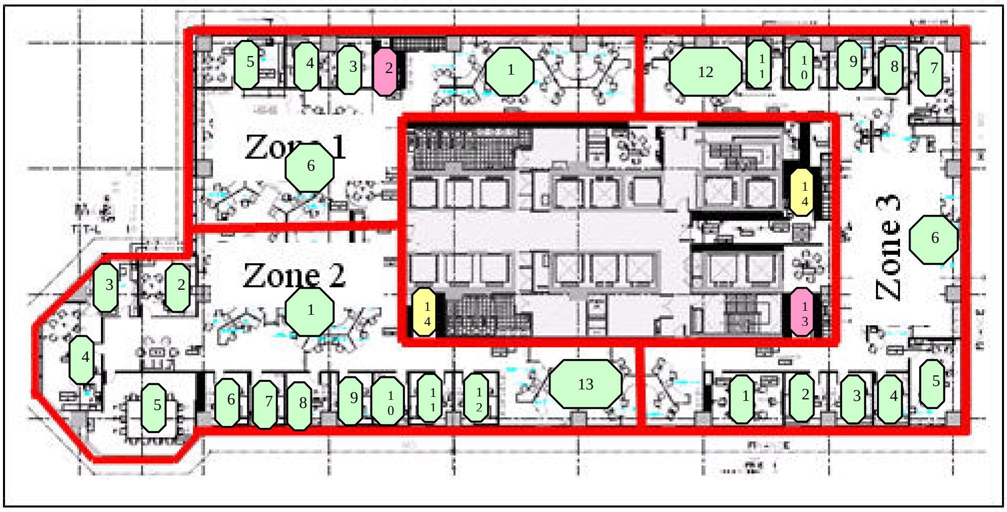


10th floor

THE VENTILATION MEASURMENT LAYOUT



11th floor

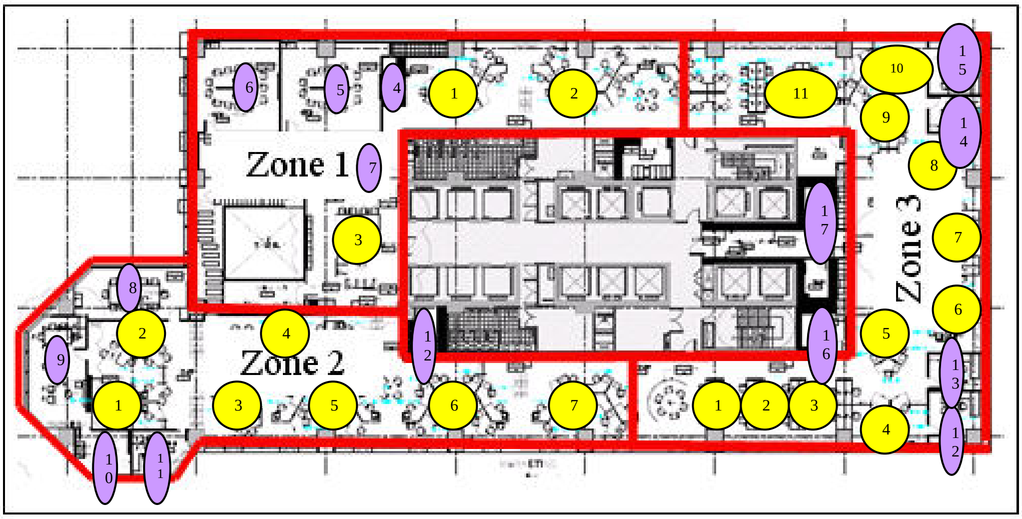


12th floor

APPENDIX K

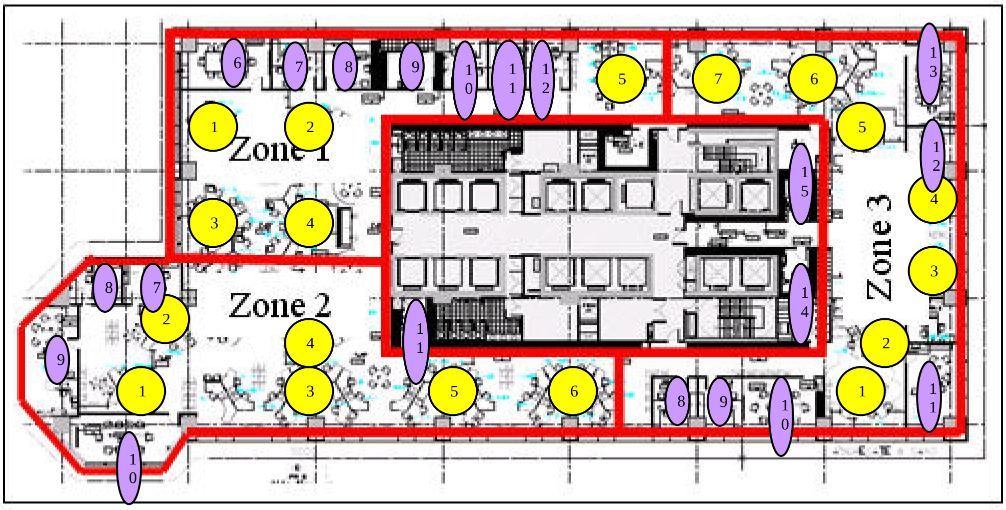
THE LIGHTING MEASURMENT RESULT

7th floor

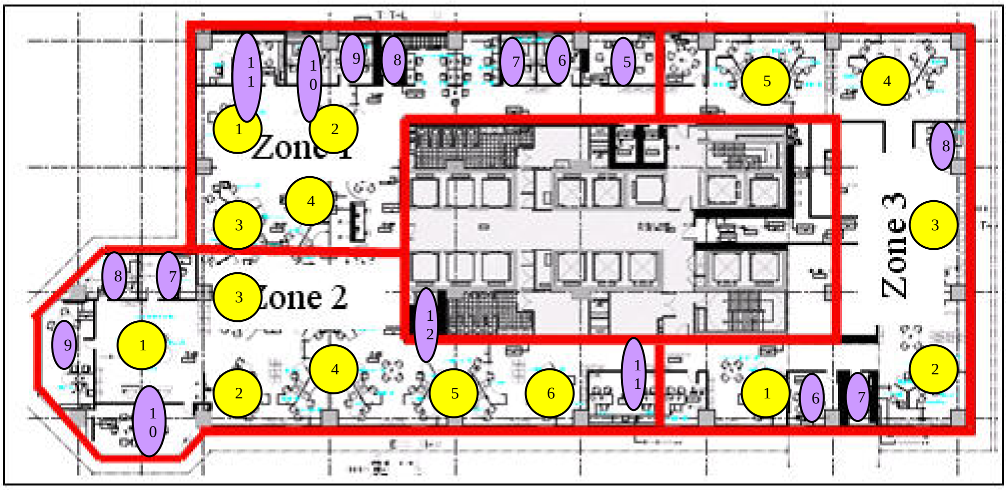


8th floor

THE LIGHTING MEASURMENT RESULT

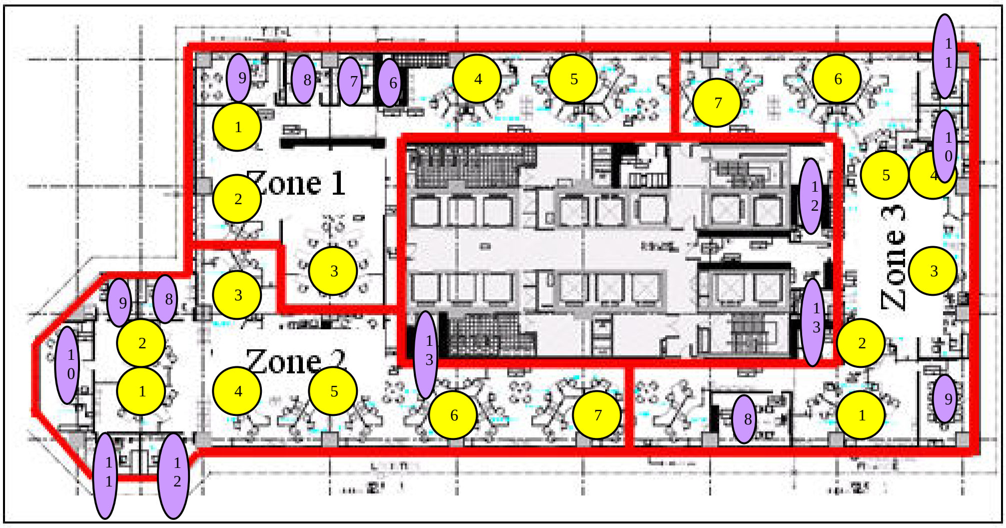


9th floor

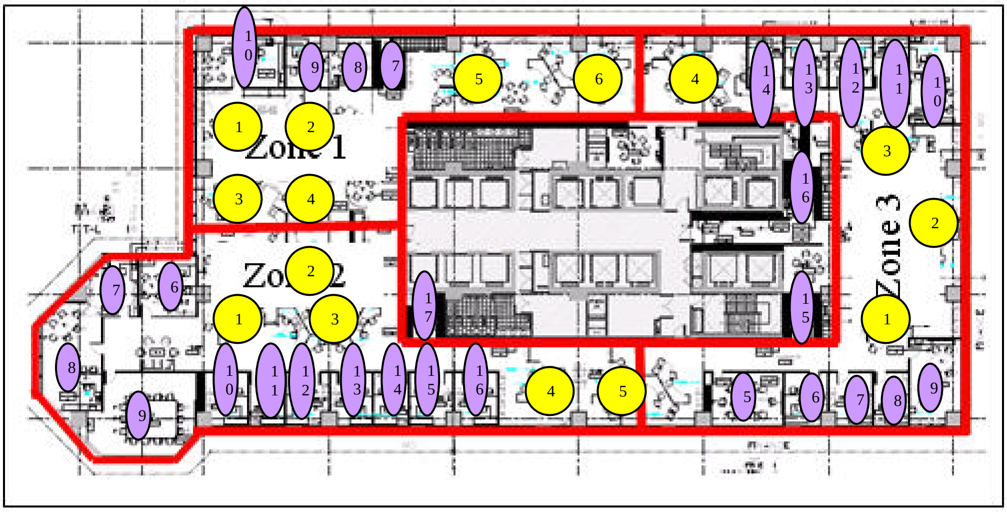


10th floor

THE LIGHTING MEASURMENT RESULT



11th floor



12th floor

THE LIGHTING MEASURMENT RESULT

Floor	Zone	Stations	Light (lux)
7th	2	1	673
		2	665
		3	615
		4	620
		5	612
		6	653
		7	624
		8	630

THE LIGHTING MEASURMENT RESULT

Floor	Zone	Stations	Light (lux)
8th	1	1	715
		2	710
		3	650
		4	660
		5	652
		6	655
		7	651
	2	1	685
		2	680
		3	671
		4	665
		5	675
		6	670
		7	670
		8	640
		9	639
		10	620
		11	634
		12	645
	3	1	663
		2	660
		3	654
		4	650
		5	649
		6	650
		7	655
		8	620
		9	625
		10	630
		11	635
		12	632
		13	640
		14	651
		15	634
		16	631
		17	629

THE LIGHTING MEASURMENT RESULT

Floor	Zone	Stations	Light (lux)
9	1	1	615
		2	620
		3	631
		4	635
		5	615
		6	620
		7	624
		8	619
		9	616
		10	619
		11	621
		12	622
9	2	1	670
		2	655
		3	650
		4	650
		5	651
		6	649
		7	632
		8	619
		9	628
		10	623
		11	631
9	3	1	625
		2	622
		3	620
		4	624
		5	615
		6	609
		7	610
		8	611
		9	616
		10	613
		11	619
		12	620
		13	609
		14	605
		15	610

THE LIGHTING MEASURMENT RESULT

Floor	Zone	Stations	Light (lux)
10	1	1	710
		2	708
		3	712
		4	711
		5	698
		6	701
		7	704
		8	700
		9	691
		10	713
		11	715
	2	1	701
		2	706
		3	696
		4	700
		5	695
		6	690
		7	679
		8	687
		9	692
		10	666
		11	650
		12	649
	3	1	625
		2	622
		3	630
		4	635
		5	629
		6	631
		7	624
		8	630
		9	610

THE LIGHTING MEASURMENT RESULT

Floor	Zone	Stations	Light (lux)
11	1	1	643
		2	650
		3	611
		4	607
		5	615
		6	619
		7	611
		8	610
	2	1	661
		2	659
		3	650
		4	643
		5	640
		6	650
		7	655
		8	650
		9	671
		10	645
		11	619
		12	622
		13	661
	3	1	631
		2	629
		3	640
		4	645
		5	641
		6	650
		7	642
		8	632
		9	610
		10	621
		11	628
		12	617
		13	626

THE LIGHTING MEASURMENT RESULT

Floor	Zone	Stations	Light (lux)
12	1	1	709
		2	705
		3	700
		4	695
		5	683
		6	679
		7	659
		8	664
		9	656
		10	671
	2	1	650
		2	638
		3	627
		4	643
		5	657
		6	643
		7	651
		8	655
		9	658
		10	618
		11	632
		12	633
		13	641
		14	640
		15	639
		16	658
		17	651
	3	1	629
		2	651
		3	648
		4	660
		5	659
		6	661
		7	643
		8	644
		9	660
		10	639
		11	631
		12	650
		13	620
		14	631
		15	639
		16	657

BIOGRAPHY

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