Jurnal Teknologi

Full Paper

IAQ ASSESSMENT IN UPNM MEDICAL CENTER

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Article history
Received
15 July 2015
Received in revised form
1 October 2015
Accepted
25 October 2015

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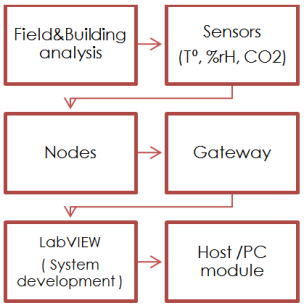
Graphical abstract



Abstract

The number of cases involving human death has increased due to scattered virus in the air. This has become a major concern on air quality, especially indoor air quality. The chemical compounds found in the building have limited exchange of outdoor and indoor, which results in building of contaminants such as CO_2 emitted by occupants activity in the building. The usage of air conditioner is unable to removes pathogens because its only circulates in air within the area. Medical Centre has a very high potential to centralize the patient with diseases related to health problems such as asthma, respiratory and cardiovascular related-diseases. This study is conducted at medical centre of NDUM, in Kuala Lumpur. The number of patients admitted was compared to the level of CO_2, temperature and relative humidity in the Medical Centre. The outdoor air index is collected from DOE Malaysia. Wireless Sensor Network (WSN) is used in this system as it can collect and disseminate the environmental data. Zigbee with 2.4GHz band is used as the wireless standard for the measurement. Sensors were attached to several points at the wall of the waiting room and were controlled by the PC module. Lab View is used to manage the data acquisition due to its ability to program a real-time system. The collected data of temperature, relative humidity and level of $C0_2$ determined the indoor air quality in the medical centre. This study brought to the assessment on the medical practice and the air quality that met the standard suggested by ASHRAE.

Keywords: Indoor air quality, WSN, labview

Abstrak

Jumlah kes yang melibatkan kematian telah meningkat disebabkan oleh virus yang berada di udara. Kebimbangan terhdap kualiti udara terutamanya kualiti udara dalam bangunan telah meningkat. Sebatian kimia yang terdapat di dalam bangunan mempunyai pertukaran udara yang terhad yang menyebabkan penghasilan bahan tercemar seperti CO2 yang disebabkan oleh aktiviti penghuni di dalam bangunan. Penggunaan penghawa dingin tidak dapat membuang patogen kerana yang hanya beredar di udara dalam kawasan yang betutup. Pusat Perubatan mempunyai potensi yang sangat tinggi untuk memusatkan pesakit yang mempunyai penyakit yang berkaitan dengan masalah kesihatan seperti asma, pernafasan dan kardiovaskularr. Kajian ini dijalankan di pusat perubatan UPNM, di Kuala Lumpur. Bilangan pesakit akan dibandingkan dengan tahap CO2, suhu dan kelembapan relatif di Pusat Perubatan tersebut. Indeks udara luar dikumpulkan daripada Jabatan Alam Sekitar Malaysia. Rangkaian Sensor Tanpa Wayar (WSN) digunakan dalam sistem ini kerana ia boleh mengumpul dan memperoleh data. ZigBee dengan band 2.4GHz digunakan sebagai standard dengan beberapa sensor ditempatkan di dinding bilik menunggu dan dikawal oleh modul PC. LabVIEW digunakan untuk menguruskan perolehan data kerana kemampuannya untuk memprogram sistem masa sebenar. Data suhu, kelembapan relatif dan tahap C02 menentukan kualiti udara dalaman di pusat perubatan. Kajian ini membawa kepada penilaian ke atas amalan perubatan dan kualiti udara yang memenuhi piawaian yang dicadangkan oleh ASHRAE.

Kata kunci: Kualiti udara dalaman, WSN, LabVIEW

1.0 INTRODUCTION

Limited exchange of outdoor and indoor air can build up contaminations that cause harms to humans and living things. Indoor air quality is defined as the air quality within and around buildings and structures. It relates to the health and comfort of buildings occupants. This research is implemented at the medical center as it has a very high potential to centralize the patient with disease related to health problems such as asthma, respiratory and cardiovascular related-disease.

The aim of this study is to recommend effective guidelines for the control and management of medical center IAQ. The airborne pollutants that existed in this premise may affect our health from various degree of severity, ranging from sick-building syndrome (SBS) to building-related illness (BRI)[1, 2]. The ventilation requirement for all areas in the medical center is using the standard set by the American Society of Health, Refrigerating, and Air Conditioning Engineers (ASHRAE)[3] to compare the collected data and the IAQ in the targeted area.

Health Informatics Center, Ministry of Health Malaysia reported that in 2009, there were about 200,718 cases reported related to diseases linked to respiratory system[4]. The major risk factors of this disease are tobacco smoke, second hand tobacco smoke, allergens, occupational agents and indoor and outdoor air pollution. The respiratory health effects of pollution increase the mortality, cancer, symptomatic asthma attacks, and other disability to conduct our daily activities, due to health problems. Previous studies on air quality proved that the indoor air quality in hospitals, healthcare and medical centers have become concerned due to the role of these area as the center of health [1, 5-11].

1.1 Indoor Air Quality

Bad air pollutions can cause harm to human and living things. Chemical compounds can be found within the buildings in decorating items such as carpets and plywood. Most of the buildings use materials that contains high chemical ingredients, especially in paints, coatings, and carpeting[12]. Apart from that, limited exchange of outdoor and indoor air can build contaminants. Indoor air pollutants are the unrecognized killer in low and middle income countries. The most affected groups are children below the age of 5 and women because they are vulnerable and most likely to be exposed to indoor air pollution daily.

Continuous air pollution cause human pandemic such as influenza, severe acute respiratory system (SARS), Ebola and Avian flu. The symptoms of seasonal flu are related to the respiratory diseases such as cold, cough, flu, fever and muscle pain. The existence of the virus in air comes from the transmitted air by coughs or sneeze, which creates aerosols containing virus. Air pollution means, presence of one or more contaminants for temporal duration that can become injurious to human life, vegetables, and animal. Air pollution can be divided into two, which is indoor and outdoor. As for indoor air pollution, it involves closed public area, such as library, houses, and office. Meanwhile, outdoor air pollution comes from the presence of solid, liquid or gases in the outdoor environment that is potential harmful to health of the occupants. The problems in air quality affect the health and comfort of the buildings occupants.

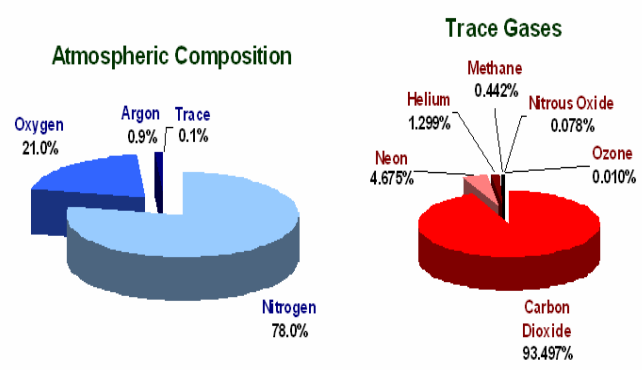


Figure 1 Composition of Atmosphere[13]

Figure 1 shows the composition of atmosphere. The atmosphere consists of different gases. Once the percentage of their composition changes, it means that the air is polluted. The pollution is caused either from the gases itself or from external sources such as dust or chemical compound. For indoor air, the CO_2 is the main source for traces of gases, because of human activities in the buildings. The concentration of

Table 1 Sources of air pollution

Factors	Source
Sources from outside the building	Sources from outside the buildings may come from contaminated air which produced by pollen, fungal, industrial pollutants, vehicle exhaust, and pollen. Vehicle produce contaminated gases from the exhaust and bad odours. Apart from that, moisture can promote microbial growth. For example, after rainfall fungus grows at the surface of the rooftops and wall of the buildings.
Equipment	Even though the purpose of heating ventilation and air-conditioning (HVAC) is to help maintain good indoor air quality through adequate ventilation with filtration and provide thermal comfort but it also have its throwback. HVAC system promotes dust, micro biographical growth and dirt. As for non HVAC system, it is produced by the emission from labs, chemical solvents, and mechanical systems.
Human activities	Body odour by human, smoking habits, cooking and housekeeping activities is also a contamination to the air. To avoid body odour, people will use deodorant and perfumes, but the chemical in the solution also contributes to air contamination. Housekeeping activities such as vacuuming, sweeping and pesticide will cause the airborne of dust and dirt to the air.
Building components	Furnishing such as carpets, textile and curtain can collect dust because it is trapped inside its texture. Meanwhile, water damage furnishing, leakage, clogged and drains also able to promote microbiological growth because the unsanitary systems for the water flow.
Building occupants	Building occupants is also an important factor to be considered as the factor in air pollution. It refers to the people or animals, which spend their time in the buildings. People itself also have the contaminated substances in their body which comes from respiratory disease, allergic, asthmatic or contact lens usage. This people are potential to brings disease and spread them to other through air. Some symptoms that attributes to air quality problems are cough, sneezing, dizziness, throat irritation or headache

indoor CO_2 level would affect the occupant's health and performance in a building[14].Indoor air quality can be defined as the air quality within and around the buildings and structures. It relates to the health and comfort of the buildings occupants. To determine the indoor air quality, it involves the monitoring of human exposure to the pollutants, data collection of the air samples and the air flow in the building by computer modeling.

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Outdoor air quality is the amount of solid, liquid and gases that are presence in the open area which is commonly degraded due to the emission of gases and smokes from vehicles. The combustion in their engines produce polluted gases to the environment such as sulfur dioxide, hydrocarbons, nitrogen oxides and carbon monoxide. Air Quality Index (AQI) is used for measurement of the standardized number and color coded index, developed by Environmental Protection Agency (EPA) is given by equation below:

(AQI) = (Pollution level / Pollution) x 100

Table 2 Air quality index provide by EPA[16]

AQI Rating	AQI Index	Effects
Good	1-25	No known harmful effects to soil, water, vegetation, animals, visibility or human health.
Fair	26-50	Adequate protection against harmful effects to soil, water, vegetation, animals, materials, visibility and human health.
Poor	51-100	Not all aspects of the environment are adequately protected from possible adverse effects. Long-term control action may be necessary, depending on the frequency, duration and circumstances of the readings.
Very Poor	>100	In this range, further deterioration of air quality and continued high readings could pose a risk to public health.

Table 2 shows the description of the AQI based on their numerical value and differentiated by different colors. It converts raw data of pollutant level received from each node to pollutant standard. Usually, the pollution standard represents the pollution from gases such as CO, NO_2, and SO_2 (20, 0.15, 0.13 ppm respectively).

1.2 Environmental Parameters

Air monitoring system is used to manage and measure the air pollutants concentrations for the area of study. Air monitoring has a few purposes such as geographical distribution pollution, determination of air pollution trends, origin of the pollution, the effect of the pollution, compliance with air quality standards and the assessments of control. The units of these systems involved in monitoring stations, sensors, data collections, data transmission, and data control to collect the determined parameters in air. Various types of sensors are used to detect the absence of gases, changes in temperature and humidity in air.

At first, the amount and composition of pollution in the targeted area must be estimated and the background of the pollution levels must be studied.

The trends of the pollution are determined by the population movements and the density of the traffic. Continuous effort must be made to obtain data that will permit the evaluation progress.

With that, the data can be collected and analyzed. In the past, initial monitoring schemes used a single monitoring stations or small number of stations, often operated by different laboratories [5]. The possibility of virus transmission is very high, due to contact and the capability of the virus to survive in high humidity and transmit to others [17].

1.2.1 Relative Humidity

One of the important environmental parameters that affect the IAQ is relative humidity. The relative humidity in confined area is measured in percentage, whereas it is ratio of the partial pressure of water vapor in the mixture, to the saturated vapor pressure of water at given temperature. According to standard given by ASHRAE the acceptable percentage of relative humidity is approximately 65% or less[18].

1.2.2 Temperature

The other parameter to be considered in IAQ is, temperature. Physics define temperature as a measurement of the average kinetic energy of the molecule in an object of system and can be measured with a thermometer or a calorimeter. The expression of temperature is in ^{0}C (degree Celsius) and ^{0}F (degree Fahrenheit) depends on which country it applied the SI unit. The comfort level for indoor air temperature is between 23ºC to 27ºC[3].

1.2.3 Carbon Dioxide

Meanwhile, US Environmental Protection Agency stated that CO_2 is the primary greenhouse gas that is emitted through human activities. It is produced during the respiration of aerobic organism and exhaled in breath by living things. The main human activity that emits CO_2 is the combustion of fossil fuel for energy and transportation, and also industrial processes. The amount of CO_2 inside buildings will help in air circulation by means of lowering the level of $C0_2$, help the healthy ventilation in the building. The accepted indoor level of CO_2 is below 1000ppm[18].

1.3 Wireless Sensor Network

The wireless sensor network (WSN) is used to monitor the air pollution. The ability of WSN to collect and disseminate the environmental data has become a popular method to assess the indoor air quality because it is small and cost effective [19-25]. WSN works independently and provides real-time monitoring[20].Sensor networks promise to revolutionize sensing in the application of a wide range of domains because of their reliability, accuracy, flexibility, cost effectiveness and ease of deployment[23].

A proper wireless sensor network (WSN) topologies must be determined to reduce its cost and complexity and at the same time improve its reliability. There are four types of topology, peer to peer, star, tree and mesh. Peer to peer allows node to communicate directly with another node. This type of topology had limited ability to collect data, since it only covers small area.

Figure 2 Conceptual of WSN

As for the star, the server is connected to centralized communications hub. Tree topology work is the main communication router, which will allow the node to communicate from one main router. Mesh WSN is the common type of sensor used, since it allows data to transmit from one another, and can be self-healing. This type of network is the most complex and can cost a significant amount of money to deploy properly. This research used star topology based on the number of nodes and the area to be covered.

2.0 METHODOLOGY

2.1 Building Analysis

Figure 3 shows the layout of the medical center of NDUM, which is located in Kem Perdana Sungai Besi, Kuala Lumpur. Sensor is placed in the middle of the waiting area. Several factors such as air flow and the location of the air conditioner was determined before the installation of the sensors. The average number of patient who visits this medical center is about 32 people daily. The results of patient who reported the symptoms of seasonal flu such as fever, cough, flu ad any respiratory problem is then compared to the current indoor air in this building.

2.1.1 Floor Plan

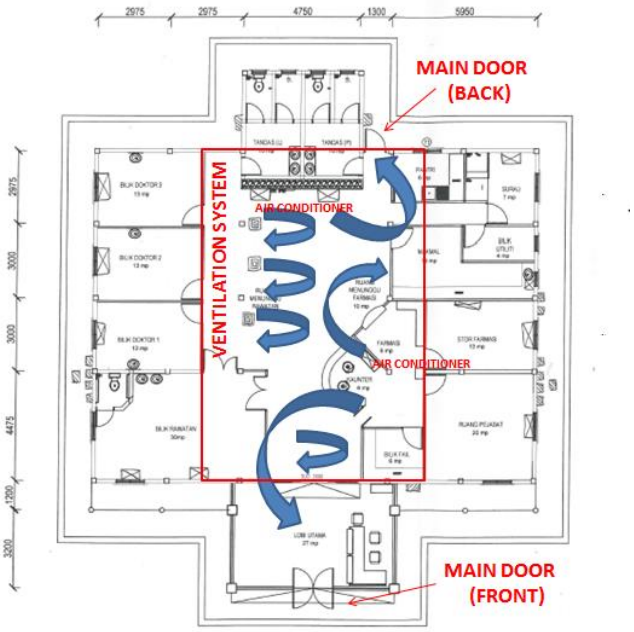

Figure 3 The medical center floor plan

This research is designed to collect data at the waiting area because the patients will wait and congregate here. There are two main doors to access the medical center. The main door is located in front of the medical center and another one is located at the rear. Both doors are kept closed during the assessment period. This medical center is operating for 15 hours, from 8am to 11pm daily. The measurement was taken continuously for 10 hours daily, from 8am to 6pm because that is the peak hour for patients to visit the medical center. The vicinity of the medical center is 3000mm height with 17050mm width.

2.1.2 Air Flow and ventilation system

The airflow in the medical center is limited because all of the windows are also closed with only two air conditioners operating at the waiting area (Figure 3). The waiting area is provided with two air conditioning and two ventilation systems. The observation recorded no growth of mold at the wall, floor, ceiling or furniture in the waiting area. The ventilation system is very good because the sliding door is open all the time but the main door of the lobby is remained closed. Thus the air in the medical center has a very wide space to circulate.

2.2 Hardware Analysis

Figure 4 illustrated the location of node that was installed in the medical center. All nodes were placed in the waiting area at different point. The first node, CO2 was placed at the main door, second node temperature at the center of waiting area and the third node, relative humidity was placed near the back main door. During the measurement, all doors and windows are kept closed.

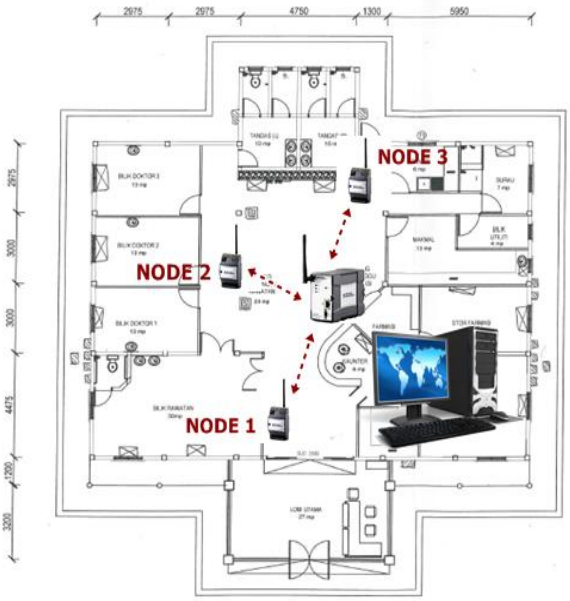

Figure 4 Location of nodes at various points

The completion of this research is achieved based on Figure 5. This research is initiated by the observation on the current situation and consciousness on the health and safety among Malaysian people, especially in medical center. After concluding the review, the research is continued by the planning on the ongoing work. As the selection of the material is very important, a longer time is taken to determine the materials to be used. A decision is arrived in using WSN system that is compatible with LabVIEW.

Based on literature review, this research comes with three parameters to be evaluated which are temperature, relative humidity and CO2. These parameters have a very strong conclusion with the recent studies about the seasonal flu.

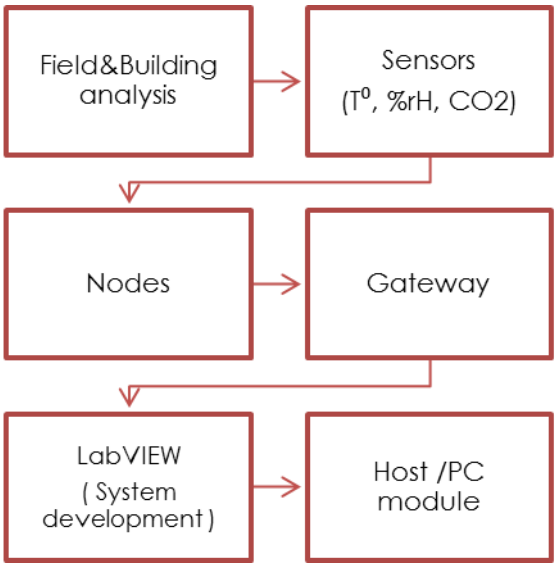

Figure 5 Flow of WSN System

Figure 6 NI-WSN Systems

The objective of data acquisition is to transmit data from various sensors through wireless network to a computer by running LabVIEW. Block diagram shows the process flow on how WSN works. This WSN system used in this research is very simple and less complex because the objective of this research is to design an affordable indoor air quality system. As shown in figure 6, the system only involves the host, receiver and transmitter.

The desktop that is fully developed with LabVIEW is the host that will keep all the data logged by the system. It is connected to the gateway that will sense the output collected by the sensor and logged them automatically to the system. The NI-WSN 9791 gateway will connect the remote NI-WSN nodes to the computer for data acquisition and control. Meanwhile, a programmable wireless receiver, WSN 3202 is connected to the sensor and acts as a transmitter.

A full NI-LabVIEW with WSN is developed to implement the experimental work. This system is designed to log and tabulate data for each 5 minutes. The data is collected daily from 8am to 6pm. The purpose of this method is because the selected medical center operates during between these hours. Meanwhile, the number of patient is most likely to peak during that period. Based on the observation, the number of patient is more during the on morning session than evening. This medical center also accepts, not only students and staff, but their immediate family members can also receive treatment at this center.

IEEE 802.15.4 has the ability for real-time data transfer. NI-WSN 9791 works as a gateway which connects the remotes NI-WSN nodes to the PC for data acquisition and control. The Ethernet becomes a bridge between wireless nodes and the PC. It connects to the host via the Ethernet cable to receive instruction from LabView.

This research is implemented in Medical Center of the National Defense University of Malaysia, a military academy in Kuala Lumpur. The number of patients who visit this medical center is about the average of 50 persons daily. As the data is collected by the system, the results are then compared to the medical report recorded by the medical center. The results of diagnose of the patients who suffer and show the symptoms of influenza will be examined.

Three sensors; temperature sensor, humidity sensor and CO2 sensor is mounted in the middle of the waiting area of the medical center. The sensor used is the CDT2000 – CO2 from HK Instruments. The specification of each sensor is shown in the Table 3.

Table 3 Specifications of sensors based on NI-WSN Datasheet

Sensors	Carbon dioxide, C02	Temperature, T^0	Humidity, rH%
Measurement Range	400…..2000 ppm	0…..50^{0}C	0…..100%
Accuracy	±40 ppm + 2% of reading	< 0, 5^{0}C	±4 % max @ 0…..50^{0}C and 10…..90%
Supply Voltage	24VAC or VDC ± 10%		
Output Voltage	0/2…..10VDC		
Current	4…..20mA		
Weight	150g		
Dimensions	99 x 90 x 31mm		

2.3 Software Implementation

To obtain the output, 3 equation is constructed based on the specification of each sensors provided by the supplier. All the sensors are able to support 2-10V voltage output. Carbon dioxide, CO_2 sensor can read from 400 to 2000ppm of concentrations in air. As for Temperature sensor, it can work at 0-50^{0}C of the normal condition and for relative humidity the range is from 0-100%.The timer is included in the block diagram

to set the data collection for each 5 minutes, (3000second/min). All the data collected is then exported to Excel. All the equation of each sensor is stated as follows:

Carbon dioxide, CO_2 (ppm) : y = 200x
Temperature (℃) : y = 6.25x – 12.5
Relative Humidity, RH (%) : y = 12.5x – 25

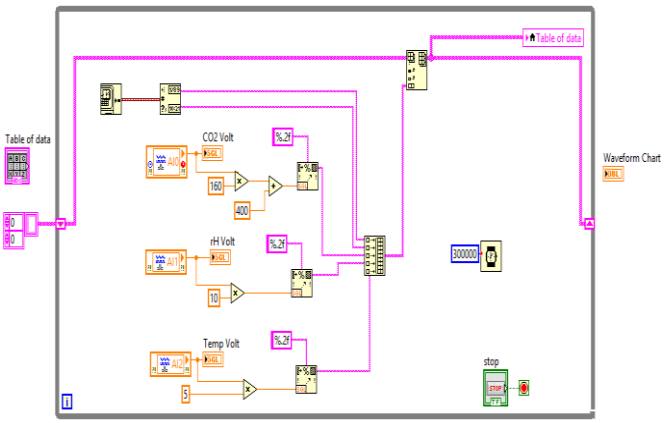

Figure 7 Block Diagram using Lab View

3.0 RESULTS AND DISCUSSION

3.1 Air Pollution Index

As shown in Figure 8- 10,, the graphs are for the collected index of the air pollution around Kuala Lumpur, provided by Department of Environment Malaysia. The selected area for this research is taken at Cheras-Sungai Besi area. Thus, the reading of air pollution was collected from the control station located in Cheras, Kuala Lumpur. The data was recorded by Ministry of Environment (DOE). Data was selected, from 6 am to 5 pm daily for 3 consecutive months to see the differentiation of each IAP between months and the current month. Blue graph indicates the morning reading; meanwhile the red graph shows the evening reading. As illustrated in the figures, all the graphs show that the API in the morning is higher than in the evening. This is due to the number of particles in air has increased and accumulated from the morning. The concentration of the ozone layer is high and will dominate the API in certain area (DOE, 2013). Overall, the API is moderate (51 to 100) and sometimes is unhealthy for sensitive group (101 to 150). At moderate condition, the air quality is acceptable, but still can affect the health of some patients who are unusually sensitive. Meanwhile, the unhealthy condition is not

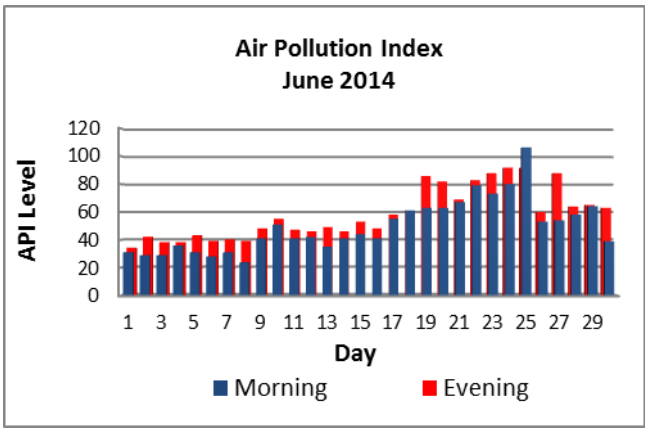

Figure 8 API for June 2014

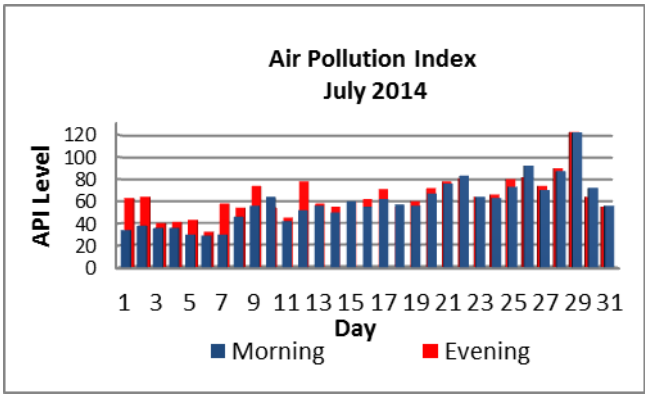

Figure 9 API for July 2014

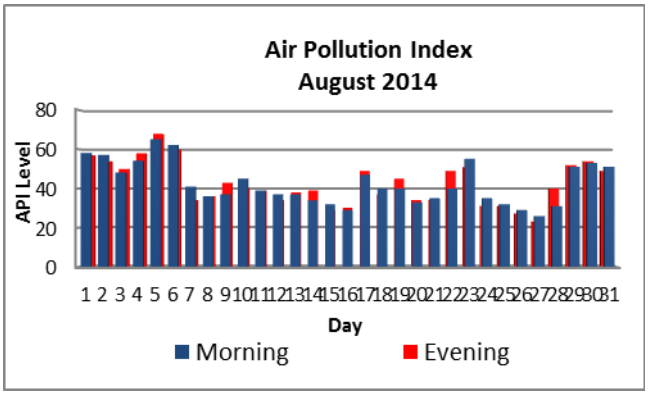

Figure 10 API for August 2014

suitable for children, older people, people with lung infections, and people who work outdoor. As can be seen, at the end of June and July (Fig. 8 and Fig. 9), the API reading exceeds 100.

Meanwhile, August (Fig. 10) shows good to moderate reading of air pollution. The WSN was used to collect data on CO_2 concentration, temperature and relative humidity for real-time monitoring and LabView is to display the data by charts. A typical sets of data collected is shown in Graph 4-7. For example, the CO_2 concentration detected by the sensor exceeded 700ppm at 10am. Additionally, the temperatures were mostly over 28°C in the afternoon and briefly lower in early morning and late afternoon.

3.2 Indoor CO_2 Concentrations (ppm) and Occupants And Patients In The Building

This data represents the similar pattern of the result for those 3 consecutive months. In this assessment the highest mean of CO_2 concentration (e.g., 737.35ppm) was found in the morning. One possible cause for this observation may be the higher number of occupants and activity in the medical center. Figure 8 shows the data for a particular day for a day on June 2014, with average reading for the day is 592.80 ± 306ppm.The concentrations of $C0_2$ is higher in the morning compared to late afternoon, with difference of approximately 37ppm. For this day, the total number of patient that visits the medical center is 17 people.

More than 10 people reported in the morning and only 1 patient reported in the afternoon. In the afternoon, there were no patient in the medical center, thus the CO_2 concentration decreases below 600ppm. The CO_2 concentration is at peak after the total number of patient reported to the medical center exceeds 12 persons. This is due to the accumulated CO_2 from the total occupants in the building. All readings show that CO_2 concentration in the medical center passed the ASHRAE standards, with reading of average from 500ppm to 700ppm.

Compared to the data from Figure 8, the API for the same day as this data, also shows significant results, whereas the API is higher in the morning compared to the evening. The API is calculated based on the data provided by DOE. Observations on Malaysians lifestyle proved that most of the pollutants are coming from various human activities such as transportation, industry and combustion. Due to the working hours from 8am-5pm, the API is at high during early in the morning and late in the afternoon. The usage of mobile transportation is at peak early in the morning (people go to work) and late afternoon (going back from work). Furthermore, the monitoring stations are located in the center of the town, thus maximum data of pollution is collected.

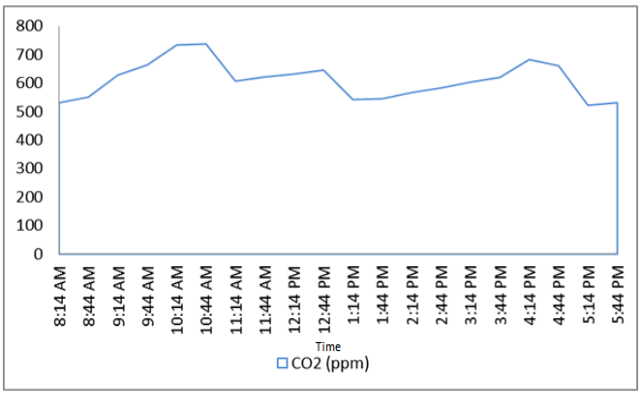

Figure 11 Carbon dioxide, CO2 (ppm)

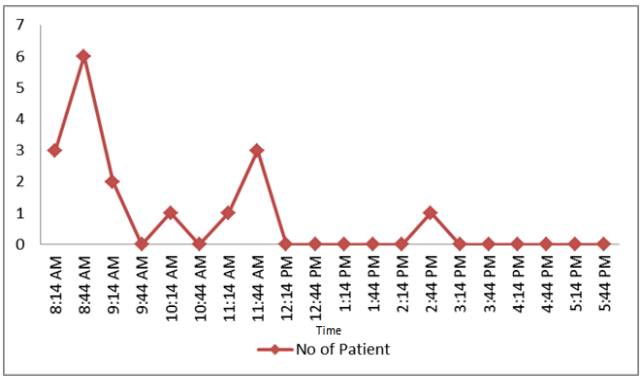

Figure 12 Number of patients

3.3 Indoor Relative Humidity (%)and Indoor Temperature (°C)

A good temperature and relative humidity will determine the thermal comfort of the occupants in a building. Relative humidity and temperature have a strong relationship to the occupants comfort whereas, higher temperature increase the evaporation rates. Meanwhile, higher relative humidity can encourage the growth of mold and mildew. As for humans, higher relative humidity will make the occupants feel chilled in cold weather and hot and sticky in warm weather. Relative humidity on this particular day shows that the percentage of the relative humidity is higher in the morning and late evening, up to 76%. Both periods show that the relative humidity has exceeded the suggested standard by ASHRAE, 65%. Since this value categorized as high relative humidity, the observation recorded many movements and some occupants begun to feel uncomfortable. As most patients come in the morning and late afternoon, the evaporation of $C0_2$ gases increases the water vapor in the building. Therefore, the relative humidity in the medical center is high in the morning and late afternoon

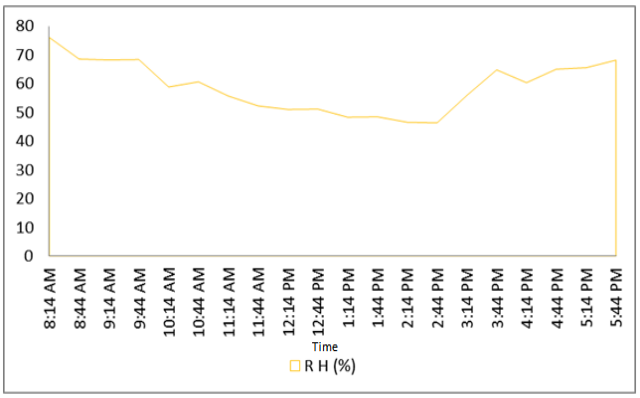

Figure 13 Relative Humidity, RH (%)

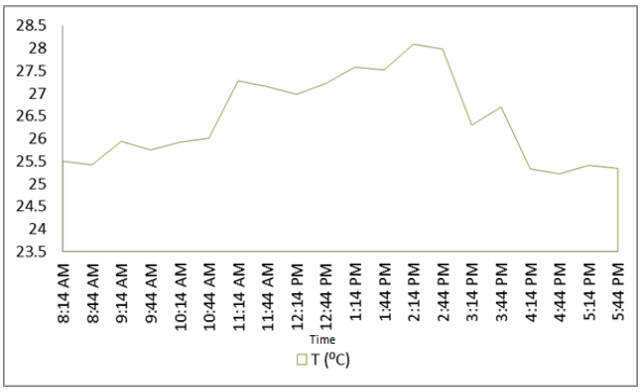

Figure 14 Temperature, T (°C)

3.4 Ventilation

In hospitals, air conditioning can affect the transmission and distribution of infectious agents[8]. The main air flow in this medical center is the main door and its air conditioning system. The airflows enter and leave the medical center through main doors and its ventilation system. As occupants breathe, they use up available oxygen and replace it with carbon dioxide. Although elevated carbon dioxide levels are generally not dangerous, this type of scenario can make patients uncomfortable and drowsy. So, it directly affects patient`s health. Based on the observation in the medical center, patients were comfortable. Throughout the monitoring period, the indoor concentration of CO_2 is ranged between 550ppm to 750ppm, which is below ASHRAE standard guidelines.

4.0 CONCLUSION

The results show that the relative humidity increases when the number of patient who are affected by seasonal flu symptoms increases. The number of patient present in medical center are also affect the concentrations of CO_2 level, whereas the number of $C0_2$ gases are increased due to human activity and patients present in the building. The alertness of air quality among the people in Malaysia is still need to be investigated. Thus, this system is highly recommended to be installed in public areas, especially in medical center, whereas it is one of the main places for people to gather and receive treatment. As we mix among each other, thus there is high potential for the seasonal flu viruses to be spread aggressively, through air. This project may bring a success to research in increasing the indoor air quality in medical center by recommending the right standard. Further investigation with longer time duration of data measurement is needed to be done to examine the indoor air quality of this medical center. It is recommended that the particle matter is measured. Meanwhile, the occupants comfort can be examine by conducting thermal comfort survey.

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