Assessment of indoor air quality parameters at Ambulatory Care Centre XYZ, Malaysia

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Abstract. Indoor Air Quality (IAQ) problems are very important and necessary to consider in hospital and health care facilities such as in AMBULATORY CARE CENTRE XYZ (ACCXYZ), Malaysia. Majority complaints made by the hospital staff at level 1, state that they felt uncomfortable and suffering coldness due to very low temperature of centralizing air-conditioning especially during non-peak hours. Therefore, five parameters pointed to be measured based on the complaints from staff due to IAQ problems especially from Heating, Ventilating, and Air Conditioning (HVAC) system. By using 4 in 1 Meter Kit, three environmental parameters recorded such as air temperature (t), relative humidity (RH) and air velocity (AV) and the average result are 22.5°C, 57.7% and 0.02 m/s, respectively. Meanwhile, two chemical parameters recorded are carbon dioxide (CO2) with 875ppm and formaldehyde (CH2O) is 0.11ppm were measured using IAQ Calc model 7545 and Formaldehyde Meter Z-300 devices value within the standard. Thus, the result shows that the HVAC system affects the IAQ parameters in ACCXYZ building through a major impact on the temperature due to patient and staff environment and also to the operation of the sensitive machine in the building.

1. Introduction

IAQ encountered wide variety factors which are temperature, relative humidity, air movement and chemicals contaminants as well as the quality of outdoor air brought inside the building [1]. IAQ problems are thoroughly correlated with the HVAC system. The installation of the HVAC system in the ACCXYZ building plays an important role in providing the comfort, good IAQ and suitable indoor thermal conditions to create cosiness working environment to the hospital staff so that they able to treat the patient well. The IAQ and thermal comfort in the building is important as it may affect the work and health of the hospital staff as they spend almost eight hours in the building every day [2].

IAQ is defined as the characteristics of the indoor air inside a building that consists of pollutants and thermal (which are temperature and relative humidity) concentration that can give effect towards health, comfort and performance of building occupants [3]. A hospital environment involves special consideration to make sure a healthy indoor air quality. The patients within the facility and the staff concerned for those patients are all directly impacted by the quality of air in the building. The hospital staff is essential in health care organizations. The indoor environment will affect productivity, morale,
health, and welfare. Poor IAQ in hospital may cause outbreaks of building-related illness (BRI) such as headaches, fatigue, eye and skin irritations and other symptoms [4].

Healthcare facilities have to pay particular care to indoor air concerns [2]. Hence, the Care Centre presence the major sector of the total health care system, where most resources are allocated are expected to function proficiently and effectively. In ACCXYZ building, most complaints made by the hospital staff at level 1 and they felt uncomfortable and suffering coldness due to very low temperature of HVAC especially during non-peak hours. According to a study carried by NIOSH 1987 [5], 529 facilities whose occupants had complaints about IAQ problems. The outcome of this survey was documented and the highest percentage goes to inadequate ventilation. Based on the study, it is specifying that the majority of IAQ problems was triggered by insufficient ventilation. Three basic parameters are controlled by the HVAC system, such as ventilation, temperature, and humidity. These three variables are interrelated and must be balanced and maintain a comfort level for the occupants [6]. Air ventilation is important to controlling indoor air contamination through dilution with fresh “ uncontaminated” (or “ clean”) outdoor air either its by natural ventilation or mechanical ventilation. Thus, the aims of this study are to recognize the IAQ major problems based on the complaints from the hospital staff, measurement on physical and chemical parameters of IAQ and to investigate the Heating, Ventilating and Air Conditioning (HVAC) system parameters.

2. Methods
In this study, ACCXYZ building consists of level 1, 2 and 3 stayed full air-conditioning area focusing on the sample points selected at every level. Thus, five departments were selected to carry out the IAQ investigation due to the most complaint recorded. The selected five departments are labeled as PHEU and OTU at level 1, EU and DCW at level 2 and SSCU at level 3.

The methodology process comprised of walkthrough inspection and field measurements according to the Guideline on Indoor Air Quality for Hospital Support Service (2015). Thus, the detail of the process is as follows;

(a) Walkthrough inspection.
EPA 2007 [8] reported and suggested to hiring an independent contractor to conduct baseline IAQ measurement. The inspection was done with the experts from hospital staff ACCXYZ, HVAC technician from Company DEF and IAQ technician from Company KLM. The process was carried out to identify potential factors that influence IAQ problems with all the departments. This paper only focuses on walkthrough inspection, meanwhile, the interview or subjective response will discuss in another paper. The sample of the questionnaire will be referred to DOSH checklist [9].

(b) Field measurements.
Five parameters were recorded during the field measurements. Measurement on IAQ data was collected for all level included three physical parameters (air temperature, relative humidity, and air velocity) and two chemical parameter (carbon dioxide and formaldehyde) by using 4 in 1 Meter Kit, IAQ Calc model 7545 and Formaldehyde Meter Z-300 devices (Source: A Flir Company (2009)) [7]. The physical measurement was collected during office hours of 9 days excluded 3 days for each level. Data were collected three times per day, morning, afternoon and evening during a sunny day. In the meantime, the chemical parameter was collected for three days together with IAQ technician from Company KLM. By using Formaldehyde Meter Z-300 to measure formaldehyde and IAQ Calc device to measure CO2. Then, all data was analysing and compared with the Hospital Support Service (HSS) IAQ guideline, 2015 [10] and also with ASHRAE standard for further assessment.
3. Results And Discussion
For the result and discussion, five physical and chemical parameter were analysed and discussed. Additional measurement of HVAC parameter was also discussed to identifying the relation between staff complaint.

3.1. Air Temperature (t)
The air temperature was collected at every level (1, 2 and 3) from 9.30 am to 4.00 pm within 9 days. The air temperature at noon measured for each level was considerably lower than other time. Table 1 shows the average result of physical parameters for every level measured and compared with the current standard. From table 2, the average air temperature recorded in the specific room (as in sub-topic 2.0) for level 1, 2 and 3 are 21.0°C, 24.0°C and 22.3°C, respectively. By referring to the air temperature data, Level 1 shows the critical area with the lowest air temperature compared to other levels. This is due to the number of hospital staff sharing their working area around 15 to 25 people for normal operating hours. Usually, patients start to occupy the area early morning (appointment with the Doctors) and start to decrease from the afternoon to the evening. Fewer people in the area may contribute to the air temperature to decrease. For that reason, hospital staff starts to complain about the coldness of the HVAC system. Meanwhile, average temperature for level 1 and 3 were slightly lower than recommended range for an acceptable indoor air temperature of 23.0°C to 26.0°C in HSS IAQ guideline and ASHRAE standard.

3.2. Relative Humidity (RH)
Table 1 also shows the average result for relative humidity in percentage (%). The average relative humidity were analysed at level 1, level 2 and level 3 with 54.0%, 58.7%, and 61.1%, respectively. In the present study, the measurement of relative humidity disclosed that the overall department was not in humid condition. Therefore, the satisfaction with relative humidity at all level is between the range 40% to 70% in HSS IAQ guideline and 30% to 68% in ASHRAE standard.

3.3. Air Velocity (AV)
Air velocity for all air-conditioning areas normally below 0 m/s due to top air supply. In this study, the air velocity measured at many points (using grid point) of each department normally occupied by the hospital staff. Level 1 can vary from 0.00 m/s to maximum of 0.17 m/s, at level 2 and 3 was 0.00 m/s as seen in Table 1. The entire airflow rate was lower than the maximum limit endorsed by the WHO standard of 0.13 m/s but further down in the range of HSS IAQ guideline of 0.15 m/s to 0.50 m/s due to the ceiling height (approximately 4.0 m) and slow airflow in the distributed ducts.

| Level | t (°C) | RH (%) | AV (m/s) |
|-------|--------|--------|----------|
| 1     | 21.1   | 54.0   | 0.02     |
| 2     | 24.0   | 58.7   | 0.00     |
| 3     | 22.3   | 61.1   | 0.00     |
| HSS IAQ Guideline | 23.0 - 26.0 | 40 – 70 | 0.15-0.50 |
| ASHRAE standard  | 23.0 - 26.0 | 30 – 68 | < 0.13   |

3.4. Carbon Dioxide (CO₂)
The concentration of CO₂ in EU and SSCU is found in the range of 675 ppm to 922 ppm (mean: 875 ppm) and 511 ppm to 873 ppm (mean: 643 ppm), respectively. According to ASHRAE standard and HSS IAQ guideline, the concentration of CO₂ is recommended as 1000 ppm for continuous 8 hours of exposure in an area. Based on this result, it is considered a safe indoor exposure condition for the occupants in the departments. Normally, respiration activity from humans is the major sources of CO₂
within an air-conditioned space. According to NIOSH US, the comfortable rate of CO₂ is between 250 ppm to 650 ppm [11].

3.5. Formaldehyde (CH₂O)
Throughout the measurement taken, a cleaning process was done in the area and generate certain odour of floor detergent. The odour of cleaning detergent contributes to the escalation of formaldehyde. The concentration of formaldehyde collected in EU ranged between 0.00 ppm to 0.11 ppm. Meanwhile, there was no problem of formaldehyde in SSCU since the reading was 0.00 ppm at all points even though these areas were covered with the whole of packaging material and fabrics. Therefore, the HVAC system preserves the concentration of formaldehyde lower than the HSS IAQ guideline and ASHRAE standard which is 0.05 ppm and 0.01 ppm.

Most home pollutants come from indoor sources such as perfumes, detergents, mosquito spray and coil, cooking process, sweeping, and etc. Household chemicals, solvents, paints, aerosols and cleaning products are also contaminated for indoor environment and can cause the growth of bacteria, fungus, mold and also toxic gaseous. So, the more air exchanges there are within the home, the more often indoor pollutants are diluted with outdoor air and this, in turn, lowers the pollution concentrations.

3.6. HVAC assessment
For essential of data collection, a measurement of the air-conditioning system parameter was tested by using a multimeter. Measurement was carried out with HVAC technician from Company DEF. The HVAC system parameter is tested for Air Handling Unit (AHU) at each department. All temperature parameters for chilled water supply, chilled water return, air supply, and air return were also recorded.

| AHU Location | Supply Air (°C) | Chilled Water Supply (°C) | Chilled Water Return (°C) | Different temperature (°C) | Return Air (°C) |
|--------------|----------------|--------------------------|---------------------------|----------------------------|----------------|
| PHEU         | 12.6           | 9.0                      | 11.0                      | 2.0                        | 21.0           |
| OTU          | 19.0           | 6.0                      | 12.0                      | 6.0                        | 24.7           |
| EU           | 16.6           | 10.0                     | 17.8                      | 7.8                        | 22.8           |
| DCW          | 19.4           | 6.5                      | 11.0                      | 4.5                        | 24.0           |
| SSCU         | 15.7           | 9.9                      | 14.4                      | 4.5                        | 22.0           |

Table 2 shows the temperature recorded at AHU unit for five departments. The temperature of return air at level 1 (PHEU) was the lowest compared to other levels this is due to the number of staff at PHEU is around 15 people. Usually, PHEU has the highest number of the patient in the morning from 8.00 am till 11.00 am and the patient received medical treatment at Clinic SE was among the hospital staff only. In the meantime, the outsider patient came to this unit usually to receive dietary and health counseling from the HEO unit. Therefore, this unit received a small number of the patient compared to other units. Then, after 11.00 am this area is busy with hospital staff only. Fewer occupants contribute to the thermal sensation of uncomfortable due to coldness as the supply air temperature to this area is 12.6°C.

Based on the interview carried out with the technician, the different temperature between chilled water supply temperature and return temperature should be ± 6°C to achieve the satisfied condition. AHU at PHEU has shown 2°C different due to the adjusted actuator valve at the chilled water return pipe. The adjustment was made by the HVAC technician right after they received a complaint from PHEU’s staff state that the unit was too cold. Furthermore, by closing the actuator valve from 30% to 40%, it will reduce the volume of chilled water flow inside the evaporator coil in the AHU thus will escalation the temperature of air supply to the unit.

According to Au-Yong, 2014 [12], Sick Building Syndrome (SBS) can be caused by improper operation or failure of the HVAC system that may lead to poor air ventilation. Norhidayah et al. 2013 [13], demonstrated that the failure to respond to the problem of poor indoor air quality can bring terrible impacts on human health and productivity. Meanwhile, Building Related Illness (BRI) is closely related to SBS and normally influence occupants in building. Building associated sicknesses are commonly
allergic reactions or infections. The allergies comprise of asthma, humidifier fever, and hypersensitivity pneumonitis. Bacteria, fungus and the virus can cause BRI infections [14].

4. Conclusions
Based on the data analysis and discussion, five physical and chemical parameters indications less impact to the indoor comfort and safety to be occupied. Meanwhile, HVAC system shows a big effect on IAQ in ACCXYZ building especially on air temperature that influenced the coldness for the staff and occupants. AHU unit will affect and influence the comfort and health condition of the occupants who are directly impacted by the quality of air in the building. IAQ is a big and important issue to ensure the comfort, health, productivity and safety from SBS and BRI symptoms.

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