Field Measurement of Airborne Particulate Matters Concentration in a Hospital's Operating Room

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Abstract. In a hospital operating room, adequate air flow and cleanliness are crucial to protect the patient from surgical site infection (SSI) during a procedure. The probability of the patient to get the infection is related to the concentration of bacteria carrying particles inside the room. This paper presents a field measurement study to quantify the concentration of particulate matters (PM) in a hospital operating room which complies with the ISO Class 7 requirements. The operating room was equipped with High Efficiency Particulate Air (HEPA) filters and a vertical laminar air flow (LAF) system. The measurements were conducted at three height levels from the floor namely 1.2 m, 1.8 m and 2.4 m. The data was logged at a rest condition, in accordance to the ISO 14644-1 requirements. A HPC300 particle counter was used to measure the concentrations of particulate matters namely PM0.5, PM1 and PM5. The results show that the concentrations of all particulate matters were higher at the height level of 1.2 m compared to other height levels. The concentration of PM0.5 was relatively higher than PM1 and PM5 in the vicinity of operating table.

Introduction

Indoor air quality in healthcare facilities has been encountered as a serious issue over the past several decades. A poor combination of air quality and particles flow leads to nosocomial infection which threatens human health. Approximately 88,000 deaths and cost upwards of $3 billion a year were due to hospital-acquired infection [1]. Surgical Site Infection (SSI), third most frequently reported nosocomial infection accounting for 14-16% of hospital-acquired infection in Sweden and United States (US) [2 & 3]. According to Centers for Disease Control and Prevention, it has been reported that almost 29,000 of patients yearly contract infections when undergoing surgery [4]. Out of this amount, 13,000 infected patients lost their lives and spent additional billions of dollars in healthcare services [4]. SSI is highly correlated with airborne pathogenic bacteria and particles [1, 4 & 5]. The sources of airborne pathogenic bacteria and particles in operating room (OR) are surgical staffs, patient, and supply air diffusers [4, 5, 6 & 7]. Aerosols and anaesthesia gas which used in OR were also recognised as airborne pollutants [8]. To prevent SSI, maintaining a low bacteria count and good airflow pattern within vicinity of an operating table are crucial. Several approaches that have been used to maintain low bacteria count are by using ventilation system [1, 4, 6 & 9] and contaminant source control by using clothing system [5 & 10]. Ventilation system design is important in healthcare facilities especially in the OR. Proper setup and configuration of ventilation system provide occupants with good air quality and prevent them from facing SSI. Nowadays, clean and unidirectional air flow is needed in the OR to reduce poor patient outcomes and substantial costs. Therefore, an ultraclean environment is required especially in surgeries involving organ transplants, heart, orthopaedics and neurosurgery [11 & 12]. There are several types of ventilation system used such as laminar flow system, conventional system and mixed system. There is no common guideline in Malaysia to determine appropriate ventilation systems in the OR. However, majorities of modern hospitals are using laminar air flow (LAF) system which complies with International Organization for Standardization (ISO) Class 7. In this system, only HEPA air diffusers are used as the air barrier and there is no air supply from the central zone. The HEPA filter is rated 99.99% efficient with particles size of 0.3 μm (PM 0.3) and above. This paper presents the results of field measurements to quantify the concentration of particulate matters (PM), relative humidity (RH) and temperature distribution inside the ISO Class 7 operating room of a private hospital in Malaysia. The goal is to examine the variation of particles concentration at different height levels and around the critical zone (operating table).

Field Measurement

Particulate Matter, Relative Humidity and Temperature Measurements. The field measurement was carried out in March 2014. It was conducted inside an operating room at Columbia Asia Hospital, Puchong. Two standards namely ISO 14644-1:1999 Classification of Air Cleanliness and IEST-RP-CC006.2 were followed during the data measurement to ensure the reliability of the measured data. To ensure a steady-state operating conditions, the ventilation system was turned-on 30 minutes prior to the data collection. The measurement was conducted at three different heights above the floor namely 1.2 m, 1.8 m and 2.4 m. Table 1 shows the specification of the operating room.

Table 1: Description of the operating room used for the field measurements

Description of operating room	
Operating System	Clean room System
Standard	ISO Class 7
Types of Air Flow Supply	Laminar
Room Dimension	Length, 4.2m Width, 5.1m Height, 3.0m
Personnel Entrance	Width, 0.9m Height, 2.1m
Patient Entrance	Width, 2.0m Height, 2.1m
Exhaust Grilles	Width, 0.22m Height, 0.46m
HEPA Diffusers	Width, 1.2m Length, 0.6m

Figure 1 shows the geometry of the OR. The clean air is supplied through 6 ceiling mounted HEPA diffusers. The air is exhausted through four sidewall grilles at the corners of the operating room. The LAF system provides a laminar air flow that covers up the perimeter of the operating table. The air would wash away any airborne particulate matters from the vicinity of the table.

Instrumentation Setup. The handheld particle counter instrument (model HPC 300) is shown in Figure 2. It was used to measure the concentrations of the particulate matters namely PM0.5, PM1 and PM5. A tripod was used to properly position the instrument at the chosen grid locations inside the operating room during the data collection.

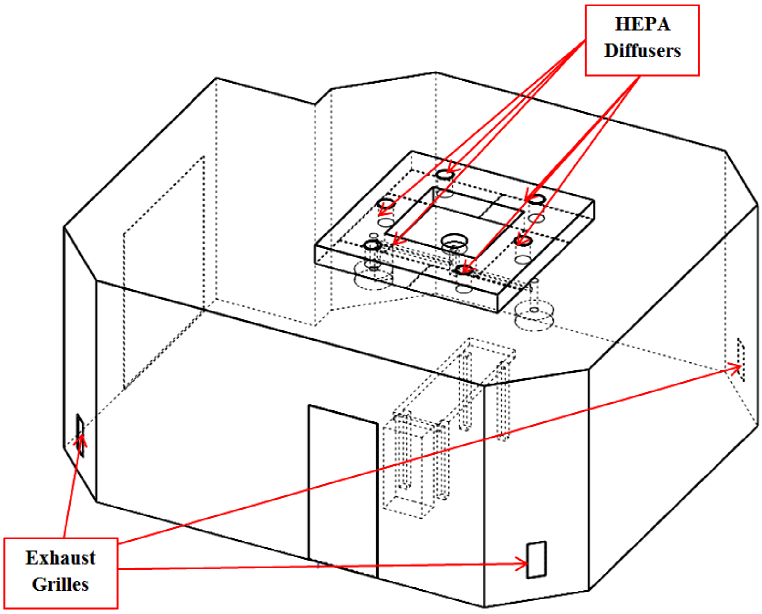
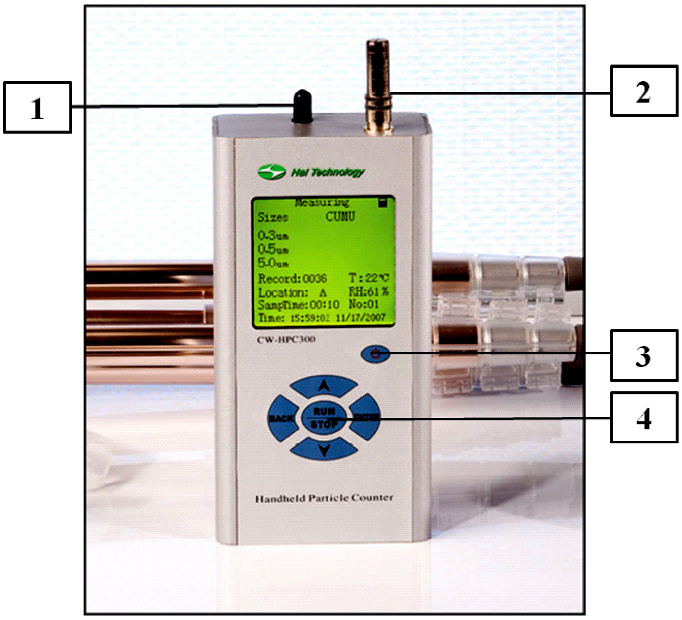


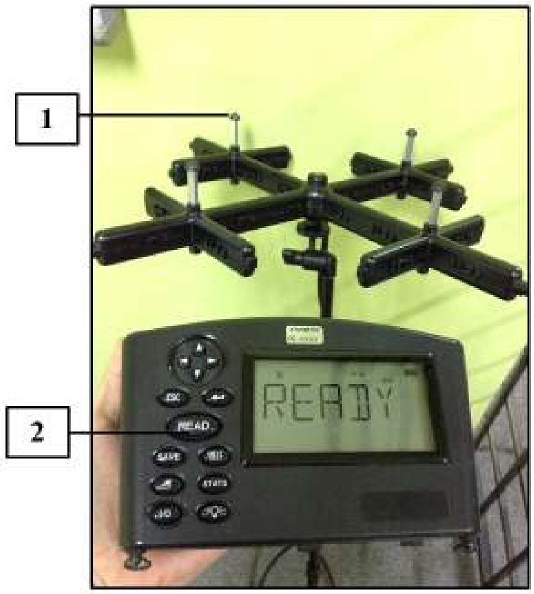
FIGURE 1 A simplified model of the actual operating room for CFD simulations.



NB: 1.Air intake; 2. Temperature and relative humidity probe; 3. Power switch; 4.Control panel

FIGURE 2 A handheld particle counter (model HPC 300).

A balometer model ALNOR EBT 721 with an accuracy of +/- 3% is shown in Figure 3. It was used to measure the average air flow velocity and pressure differential inside the OR. The average air flow velocity was measured at the face area of the HEPA diffusers.



NB: 1. Air velocity probe; 2. Control panel

FIGURE 3 A balometer (model Alnor EBT 721).

Result and Discussion

Concentrations of PM0.5, PM1 and PM5. The clean air was supplied into the OR via 6 HEPA diffusers mounted on the ceiling. The air flow rate of each diffuser was $0.35 m^3/s$, giving an air change rate of $65 h^{-1}$. The exhaust air left the room through four return grilles, placed the corners of the room. The operating table of 1.1 m height was placed at the centre of the room.

Figure 4 shows the 12 grid locations where particle concentrations were measured. The variation of particle concentrations with the grid locations, at a height of 1.2 m above the floor is shown in Figure 5. This height was chosen because patient can possibly be exposed to bacteria carrying particles during surgery. It can be seen from this figure that the concentrations of all the particles are lowest at the grid points 6 and 7 since both points are directly located under the HEPA diffusers. The air from the diffuser might have washed away the particles from these locations. At this height level, the concentration level of PM0.5 is the highest compared with the others, especially at grid locations 5 and 11. This could be because the locations of these grids are close to the disposal dustbin and mobile equipment table.

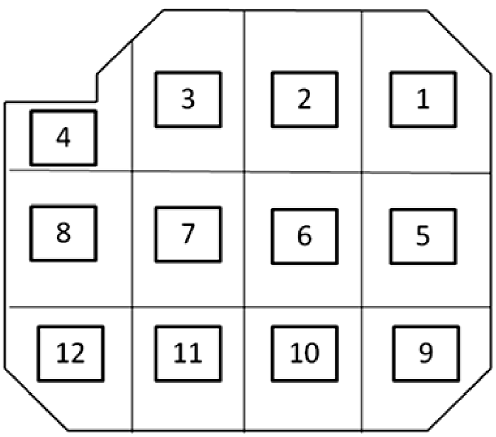


FIGURE 4 Sampling grid locations for data measurement (plane height of 1.2 m).

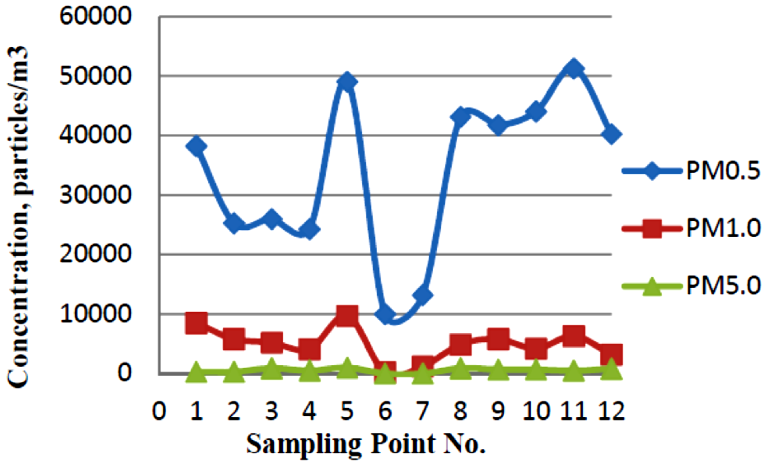


FIGURE 5 Variation of particles concentration with sampling locations (plane height of 1.2 m).

Figure 6 shows the eight grid locations where particle concentrations were measured on a plane of height 1.8 m above the floor. Figure 7 shows the variation of particle concentrations with the grid locations on this plane. It can be observed from this figure that the particle concentration of PM0.5 is the highest at grid location 5. In general, the concentrations of PM0.5 is higher at all grid locations on this plane, compared to all the other particles.

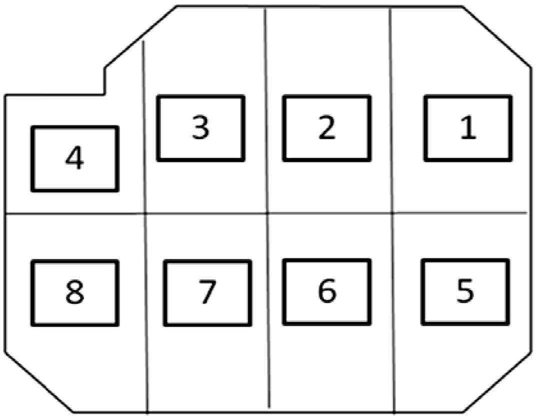


FIGURE 6 Sampling grid locations for data measurement (plane height of 1.8 m).

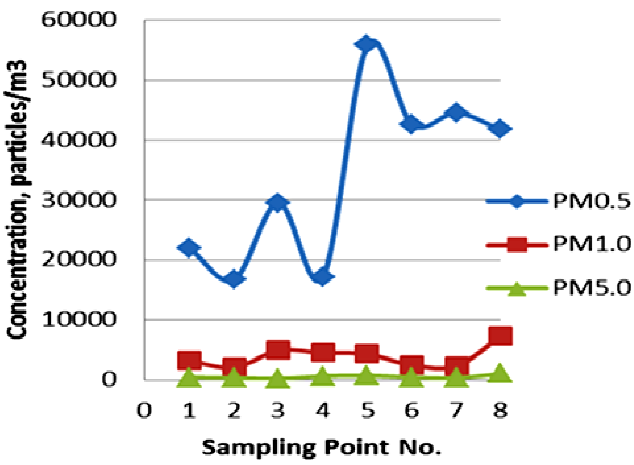


FIGURE 7 Variation of particles concentration with sampling locations (plane height of 1.8 m).

Figure 8 shows the grid locations on a plane at a height of 2.4 m above the floor. The variation of particle concentrations with the grid locations on this plane is shown in Figure 9. It can again be seen that the concentration level of PM0.5 is still the highest compared with other particles at all the grid locations. The highest concentration occurs at grid location 4.

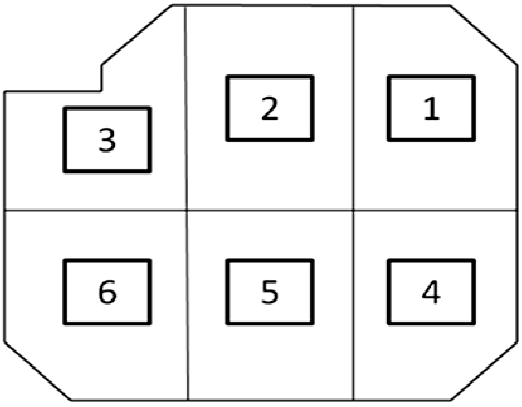


FIGURE 8 Sampling grid locations for data measurement (plane height of 2.4 m).

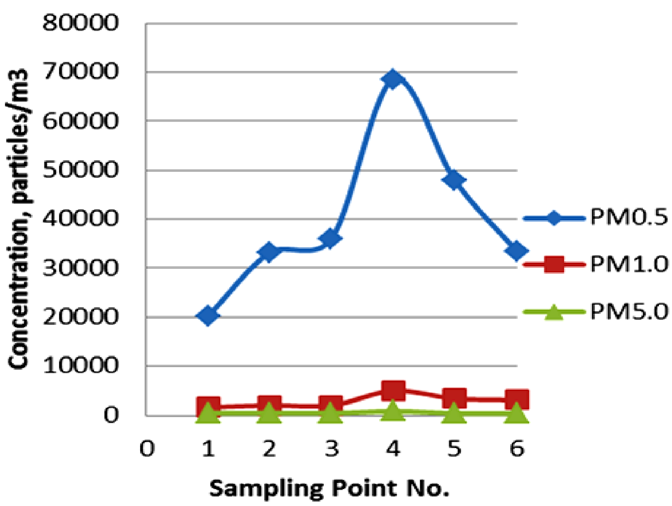


FIGURE 9 Variation of particles concentration with sampling locations (plane height of 2.4 m).

Relative Humidity And Temperature Distribution. Relative humidity and temperature at three different levels were also measured during the field measurement. It was found that the relative humidity (RH) readings were between 55% to 61% whereas temperatures were between 18.3°C to 19.5°C. The variations of RH and temperature with grid locations on planes at the height of 1.2 m, 1.8 m and 2.4 m are shown in Figures 10, 11 and 12, respectively. It can be seen from Figure 10 that the values of RH are fluctuating between 57% to 61% and the values of temperature fluctuate between 18.3°C to 19.3°C. In general, the temperature and RH values are higher than the upper limit set in the ISO standard recommendation. The range of fluctuations in the RH and temperature of the air are small and therefore can be considered to have negligible effects on the particles transport.

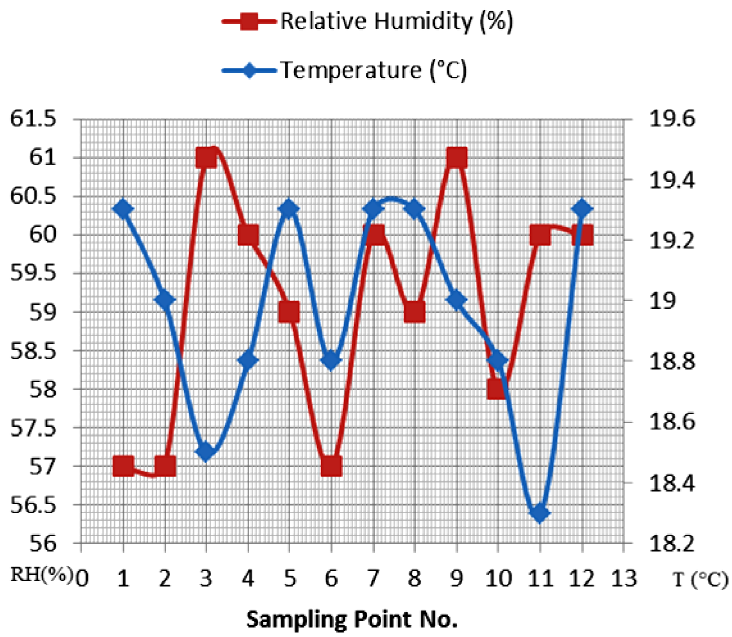


FIGURE 10 Variation of RH and temperature with grid locations (plane height of 1.2 m).

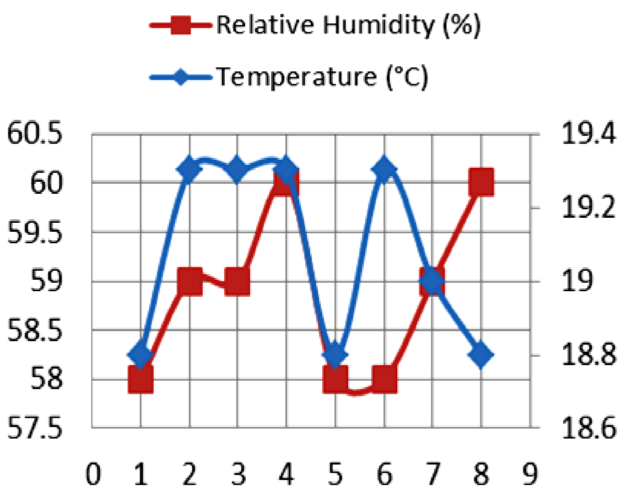


FIGURE 11 Variation of RH and temperature with grid locations (plane height of 1.8 m).

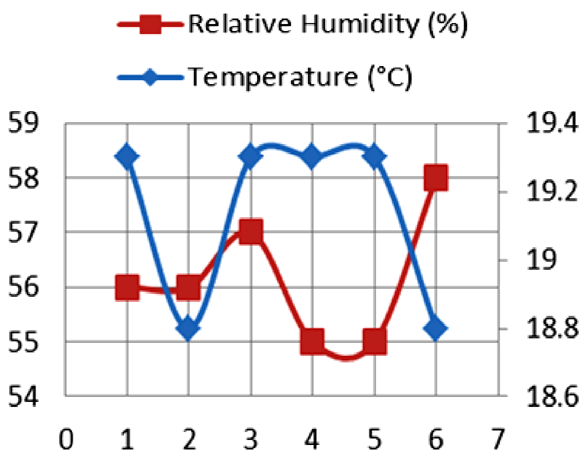


FIGURE 12 Variation of RH and temperature with grid locations (plane height of 2.4 m).

It can be observed from Figures 11 and 12 that the fluctuations of RH at the plane heights of 1.8 m and 2.4 m are between 55% to 60%. These values fall within the limit recommended by the ISO

14644 standard. However, the fluctuations of temperature on these planes are slightly beyond the limit specified by the ISO 14644 standard, which is by 0.3°C.

CONCLUSION

The following are some major findings from this study:

- Particle concentration levels of PM0.5, PM1 and PM5 were found to be significantly higher at a plane 1.2 m height above the floor.
- The concentrations for PM0.5, PM1 and PM5 were highest at the grids located close to the equipment table and disposal dust bin.
- The concentration of PM0.5 was the highest compared with other PMs at all grid locations.

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