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Original Article

Health Risk Assessment and Covid-19 Infection Rate by Using Bacterial Aerosol in Healthcare Workers in a Tertiary Care Hospital in Thailand During SARS-CoV-2 Pandemic

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ABSTRACT

Introduction: Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is a worldwide transmission and healthcare worker is the risk group. Therefore, the infection rate and health risk assessment from exposure to airborne transmission for healthcare workers were performed.

Methods: This cross-sectional study was carried out on 106 healthcare workers at four selected service areas in Songklanagarind Hospital, Thailand, from February to September 2021. The N6 impactor was used with simultaneous measurement of temperature, relative humidity, and wind speed. The general characteristics of subjects and hospitals were collected by questionnaire and presented by descriptive statistics.

Results: Most of the participants were female and they worked more than 8 hours per day. The bacteria concentration was highest in the Pediatric Outpatient Department (1837.46±177.52 cfu/m^3). The lowest chronic daily intake and hazard quotient with no threshold (4.86±3.81, 95%CI: 3.59, 6.13) were at Covid-19 Intensive Care Unit - due to negative pressure ventilation in this room was effective in reducing the airborne concentration of the pathogens. Overall, the hospital's hazard index with no threshold (30.87±35.25, 95%CI: 23.91, 37.83) was higher than 1.0, indicating that bacterial bioaerosol may affect healthcare workers' health. The highest confirmed Covid-19 case was at Acute Respiratory Infection Clinic (19.29±10.67 cases/week). The probability of infection by SARS-CoV-2 in healthcare workers was high at Acute Respiratory Infection Clinic (1.0) and Covid-19 Intensive Care Unit (0.998±0.002, 95%CI: 0.998, 0.999).

Conclusion: Therefore, inhalation reference concentration for hospitals should be as low as possible and appropriate ventilation systems should be implemented with adherence to standards to protect healthcare workers.

Keywords: Covid-19, infection rate, occupational exposure assessment, tertiary care hospital

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Introduction

The coronavirus disease 2019 (Covid-19) is an infectious pneumonia caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). SARS-CoV-2, bioaerosol, could be transmitted from an infected person to others through direct human-to-human contact and via respiratory droplets/aerosols.[1,2,3,4] The infection fatality rate of Covid -19 in hospitals was 0.2% (Norway), 0.95% (Connecticut, USA), 50.2% (Mexico) and 64.1% (Germany).[5,6,7,8] Bioaerosol is an important factor in determining indoor air quality (IAQ), especially in hospitals because of related adverse health effects that can include infectious diseases, acute toxic effects, allergy, asthma and nowadays is SARS-CoV-2.[9,10,11] SARS-CoV-2 are enveloped positive-stranded RNA viruses with the RNA packaged within an outer fatty or lipid membrane and require host cells. Patients with COVID-19 have co-infections with bacterial pathogens such as *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Stenotrophomonas maltophilia*.[12,13,14,15] Bacterial and fungal aerosols are the most common microorganisms in hospital environments, with standard values up to 500 cfu/m^3.[16] However, The American Conference of Governmental Industrial Hygienists (ACGIH) suggests that there is no occupational health limit for bioaerosol level.[17] There were several factors can affect the density, distribution and diversity of bioaerosols in a hospital environment, such as season, temperature, humidity, building construction and materials, room design, indoor ventilation system, work shifts, types of ward, disinfection, and the numbers and activities of patients, visitors, and healthcare workers.[18,19,20] Also the ultraviolet germicidal irradiation system can make a difference, especially in the limited space of an ICU.[21] Therefore, the concentrations of bacteria and fungi in all hospital environments exceeded the standards, indicating that these bioaerosols may affect a healthcare worker's health and also patients.[22,23]

Air ventilation systems can reduce and control the transmission of bioaerosols in hospitals. Bozic *et al*. (2019) reported that the concentration of bacteria and fungi in hospital areas with heating, ventilation, and air conditioning (HVAC) systems (400 and 220 cfu/m^3) was lesser than in areas without HVAC systems (700 and 350 cfu/m^3).[24] While hospital areas with HVAC systems had low levels of bioaerosol contamination but without HVAC systems they tended to have medium levels (500-999 cfu/m^3).[25] In addition, a relationship between the concentrations of bacteria and fungi and relative humidity has been found.[26]

In the context of infection rate in hospitals, the probability of infection should be investigated. The Wells-Riley model was a quantitative infection risk assessment method to determine respiratory infectious diseases, especially indoor air environment and have been used since 1974.[27,28] MERS, SARS, and COVID-19 are the most serious respiratory infection disease. For the Wells-Riley model, the infectious airborne particles were assumed to be the random distribution and can demonstrate the important removal mechanisms for airborne infectious agents.[28]
Songkla is one of the provinces that were severely impacted by Covid-19 in 2020-2021. This study was carried on at Songklanagarind Hospital, Hat Yai, Songkhla province, Thailand. To the best of the authors' knowledge, the probability of infection and occupational health risk from exposure to SARS-CoV-2 have never been reported for this hospital. Therefore, this study aimed to determine the probability of infection from the airborne transmission of SARS-CoV-2 using walk-in suspected Covid-19 patients and to analyze occupational health risks from exposure to SARS-CoV-2 for healthcare workers based on bacterial concentrations in different ventilation systems in Songklanagarind hospital healthcare environment.

Methods

Study Area and General Characteristics

To deal with the large numbers of Covid-19 patients, Songklanagarind Hospital has measures to control the SARS-CoV-2 airborne transmission indoors, such as hand washing with alcohol, use of disinfectants for surface cleaning, assessments of body temperature, patient screening, and isolation of acute respiratory infection clinic. In this study, the Internal Medical Outpatient Department (MOPD), the Acute Respiratory Infection Clinic (ARI), the Pediatric Outpatient Department (POPD) and Covid-19 Intensive Care Unit (CVICU) were purposively sampled for investigating the infection rate and bacterial concentrations in this university hospital.

Study Subject and Confirmation Covid-19 Case

A cross-sectional study was carried out with voluntarily participating healthcare workers who work at The Internal Medical Outpatient Department (MOPD), the Acute Respiratory Infection Clinic (ARI), the Pediatric Outpatient Department (POPD) and Covid-19 Intensive Care Unit (CVICU) between February and September of 2021. Ethical permission for the study was obtained from the Ethics Committee of the Prince of Songkla University (REC No. 63-255-9-2). Informed consent was taken from all subjects after the purpose of the study was explained to them. Standard ethical considerations were followed during the study, with total confidentiality of any obtained data. The infectious disease doctor and researcher diagnosed the walk-in suspected Covid-19 patients by using the laboratory results. The total number of whom have been diagnosed with Covid-19 (confirmed Covid-19 case) were collected from the Hospital Information System (HIS) database of Songklanagarind Hospital.

Questionnaire

Data collection was by use of a designed questionnaire organized into two sections. The first section covered general characteristics such as gender, age, and weight. The second section included work characteristics (work experience, work hours per day, workdays per week, the number of suspected and confirmed Covid -19 cases per day and contact frequency with suspected and confirmed Covid -19 cases).

Environmental, Bioaerosol Sampling and Analysis

The bioaerosols were collected by using a single-stage (N6) viable cascade impactor (Model TE-10-890, Tisch Environmental, USA). The aerodynamic diameter was less than 0.65 μm. Air sampling was done for 5 min at a flow rate of 28.3 L/min at 1.5 m above the floor level, to sample airborne bacteria. The indoor bioaerosol was determined from a total of 3 samples for each study site, which were placed at the center of each ward, and represented the morning period (09:00-12:00) of hospital services during June – September 2021.

The total amount of bacteria was cultured using Trypticase soy agar medium and incubated at 37°C for 2 days.[29] The concentration of airborne bacteria was presented as cfu/m^3. To investigate the environmental factors, wind speed, temperature (°C) and relative humidity (% RH) were measured simultaneously with bioaerosol sampling by direct-reading instruments (VelociCal, TSI, Germany).

Health Risk Assessment, Hazard Quotients and Hazard Index

The main exposure route of healthcare workers was inhalation. The health risks of bioaerosols for full-time healthcare workers in hospitals were calculated based on the following equation.

$$CDI = (CA \times IR \times ET \times EF \times ED) / (365 \times AT \times BW) \quad (1)$$

Here CDI represents chronic daily intake (mg/kg-day), CA denotes the concentration of bioaerosols in the hospital (mg/m^3), IR is the inhalation rate (m^3/h), ET is the exposure time (h/day), EF and ED are exposure frequency (day/year) and exposure duration (year); 40 years for occupational health exposure assessment.[30] In addition, AT and BW are average lifetime (years) and body weight (kg). An average lifetime for non-carcinogenic assessment was 40 years. However, the estimated working year for Thai registered nurses was 38 years.[31]

The non-carcinogenic bioaerosols were assessed by hazard quotient (HQ), which is the ratio of CDI and an inhalation reference concentration (RfC, mg/kg/day), and no threshold, 50, 100, and 500 were used in this study, as follows.

$$HQ = CDI / RfC \quad (2)$$

HQ ⩽1.0 is considered acceptable, while HQ >1.0 is adverse for the non-carcinogenic effects of concern.

The non-cancer health impacts were represented by the hazard index (HI), which is calculated by summing all of the HQ at a specific location.

$$HI = \Sigma HQ \quad (3)$$

If HI ⩽ 1.0 there is an acceptable hazard, while if HQ >1.0 there are likely adverse health effects.

Probability Infection

The Wells-Riley model was used in this study to determine the relationship between the air exchange rate and the probability of infection.[32]

$$PI = C/S = 1- e^{-Iqpt/Q} \quad (4)$$

Here *PI* represents the probability of infection (-), *C* is the number of susceptible individuals to become infected (-), *S* is the number of susceptible individuals (-), *I* is the number of infectious individuals (-), *p* is the pulmonary ventilation rate of a person (m^3/h), *q* is the generation rate of infection quanta (h^{-1}), t is the exposure time (h), and *Q* is the room ventilation rate with clean air (m^3/h). The room ventilation rates were calculated by wind velocity for MOPD, ARI, POPD and CVICU.

Statistical Analysis

The descriptive statistics used in this study included mean, standard deviation, percentage and 95% confidence interval. The Pearson correlation coefficient (*r*) and linear regression between relative humidity and temperature was performed.

Results

During the study period, MOPD has the highest number of patients (178±48.6 subjects, min = 122, max = 238) but CVICU has the lowest number of patients (7 subjects). CVICU has 17 beds (in-patient department) but POPD, MOPD and ARI (out-patient department) have no bed. Healthcare workers in ARI and CVICU were 150.85±24.09 and 31.24±10.04 subjects (volunteer and rotate shift) while POPD and MOPD were routine and daytime shifts with only 19 and 33 subjects, respectively. The patient waiting hall and service area of the POPD, MOPD, ARI and CVICU were 576, 432, 108 and 576 m^2, respectively. MOPD and ARI had nearly the same velocity rate and temperature, whereas CVICU had the lowest velocity rate and temperature. The relative humidity conditions were in the range of 65.40-72.15% (Table 1).

Table 1: General characteristics of four study areas during the study period

Parameter	POPD	MOPD	ARI	CVICU
No. of Patient (average±SD, min-max)	54.7± 9.87 (48 – 66)	178±48.6 (122 – 238)	13.0±2.42 (8 – 16)	7
No of Bed	-	-	-	1-4 bed per room Totally 17 beds
No. of Health care workers	19	33	150.85±24.09	31.24±10.04
Service	Outpatient, patient with appointment and walk-in	Outpatient, patient with appointment and walk-in	Outpatient with walk-in	Inpatient with intensive care
Patient waiting hall and service area (m^2)	576 (W=24, L=24)	432 (W=24, L=18)	108 (W=6, L=18)	576 (W=24, L=24)
Velocity (m/s) (average±SD)	0.11±0.03	0.34±0.08	0.37±0.18	0.04±0.04
Temperature (°C) (average±SD)	26.74±0.25	30.44±1.05	30.94±1.01	22.45±1.29
Relative humidity (%) (average±SD)	65.49±2.52	72.15±4.20	67.31± 4.09	65.40 ± 6.76

The distribution of general characteristics of participants is shown below (Table 2). A questionnaire was completed by 106 healthcare workers at the four selected areas MOPD, ARI, POPD, and CVICU.

Most of the participants are female (94.33%), and the mean age was 38.60 ± 11.09 years. CVICU had the most subjects (35.9%) working in rotated shifts. The work hours and workdays of participants are normally 8-9 hours per day and 5-6 days per week. Healthcare workers from POPD (18.33±10.23), MOPD (18.24±12.01) and ARI (18.38±11.95) had similar work experience levels, while CVICU had the least (8.24±5.99) years of experience. POPD staff had the largest number of suspected and confirmed Covid -19 cases per day (⩾ 5 cases per day: 82.2%) and the highest contact frequency with suspected and confirmed Covid -19 cases (⩾ 5 times per day: 82.2%).

Table 2: General characteristics of subjects voluntarily participating in this study (n=106)

Parameter	POPD	MOPD	ARI	CVICU
Subject (n, %)	19 (17.9%)	18 (17.0%)	31 (29.2%)	38 (35.9%)
Job type	Routine and daytime shift	Routine and daytime shift	Volunteer and rotate shift	Volunteer and rotate shift
Gender				
-Male	1 (5.3%)	0 (0%)	3 (9.7%)	1 (2.6%)
-Female	18 (94.7%)	18 (100%)	28 (90.3%)	36 (94.8%)
-Not specified	0 (0%)	0 (0%)	0 (0%)	1 (2.6%)
Age (Years, Mean ± S.D.)	42.68±9.83	44.06±11.07	41.43±12.20	31.54±6.64
-< 40				
- ≥ 40	7 (36.8%)	6 (33.3%)	13 (41.9%)	31 (81.6%)
-Not specified	12 (63.2%)	12 (66.7%)	17 (54.9%)	6 (15.8%)
	0 (0%)	0 (0%)	1 (3.2%)	1 (2.6%)
Weight (kgs)	57.67±9.78	58.89±7.70	59.21±17.23	54.89±9.67
Work experience (years)	18.33±10.23	18.24±12.01	18.38±11.95	8.24±5.99
- < 10	4 (21.1%)	4 (22.2%)	7 (22.6%)	24 (63.2%)
- ≥ 10	14 (73.7%)	13 (72.2%)	22 (70.9%)	14 (36.8%)
-Not specified	1 (5.3%)	1 (5.6%)	2 (6.5%)	0 (0%)
Working Hour per day	8.37±0.60	9.00±0.97	8.52±0.63	8.63±0.79
- < 8	6 (31.6%)	13 (72.2%)	14 (45.2%)	17 (44.7%)
- ≥ 8	13 (68.4%)	5 (27.8%)	17 (54.8%)	21 (55.3%)
Workday per week	5.24±0.54	5.56±0.70	5.42±0.56	5.47±0.73
- ≤ 5	15 (78.9%)	10 (55.5%)	19 (61.3%)	17 (44.7%)
- > 5	4 (21.1%)	8 (44.5%)	12 (38.7%)	21 (55.3%)
Number of Suspected and confirmed Covid -19 cases per day				
- < 5	3 (15.8%)	11 (61.1%)	13 (41.9%)	8 (21.1%)
- ≥ 5	16 (82.2%)	2 (11.1%)	10 (32.3%)	29 (76.3%)
-uncountable	0 (0%)	1 (5.6%)	3 (9.7%)	0 (0%)
-Not specified	0 (0%)	4 (22.2%)	5 (16.1%)	1 (2.6%)
Contacting Frequency of Suspected and Confirmed Covid -19				
- < 5	3 (15.8%)	7 (38.9.2%)	14 (45.2%)	31 (81.6%)
- ≥ 5	16 (82.2%)	2 (11.1%)	9 (29.0%)	7 (18.4%)
-uncountable	0 (0%)	8 (44.4%)	2 (6.5%)	0 (0%)
-Not specified	0 (0%)	1 (5.6%)	6 (19.3%)	0 (0%)

Note: Data are presented as mean±SD, or n (%)

ARI had the most confirmed Covid-19 cases, 19.29±10.67 per week, while POPD and MOPD had no confirmed Covid-19 cases. CVICU showed the lowest concentration (259.72±161.61 cfu/m^3) of total bacteria while POPD had the highest concentration (1,837.46±177.52 cfu/m^3). All the hospital areas were generally contaminated with bacteria.

Relative humidity and temperature are the most widely studied factors affecting airborne virus infectivity. The averages temperatures of CVICU, POPD, MOPD, and ARI were 22.45±1.29, 26.47±0.25, 30.44±1.05, and 30.94±1.01 Celsius degree, respectively, while their percentage of relative humidities were 65.40±6.76, 65.49±2.52, 72.15±4.20, and 67.30±4.09 (Table 1). The relationship between relative humidity and temperature had a wide range of correlations (R^2 = 0.11 to 0.95) in this study (Figures 1a-d). The negative correlation was found at MOPD and ARI clinics which used general and mechanical (fan) ventilation while the positive correlation was found at CVICU and POPD clinics which had a negative pressure room and using air change per hour controlling unit, respectively. A high potential for Covid-19 contamination (low temperature and low relative humidity) may occur when the relationship between temperature and relative humidity was matched at CVICU in a negative pressure room (Figure 1b).

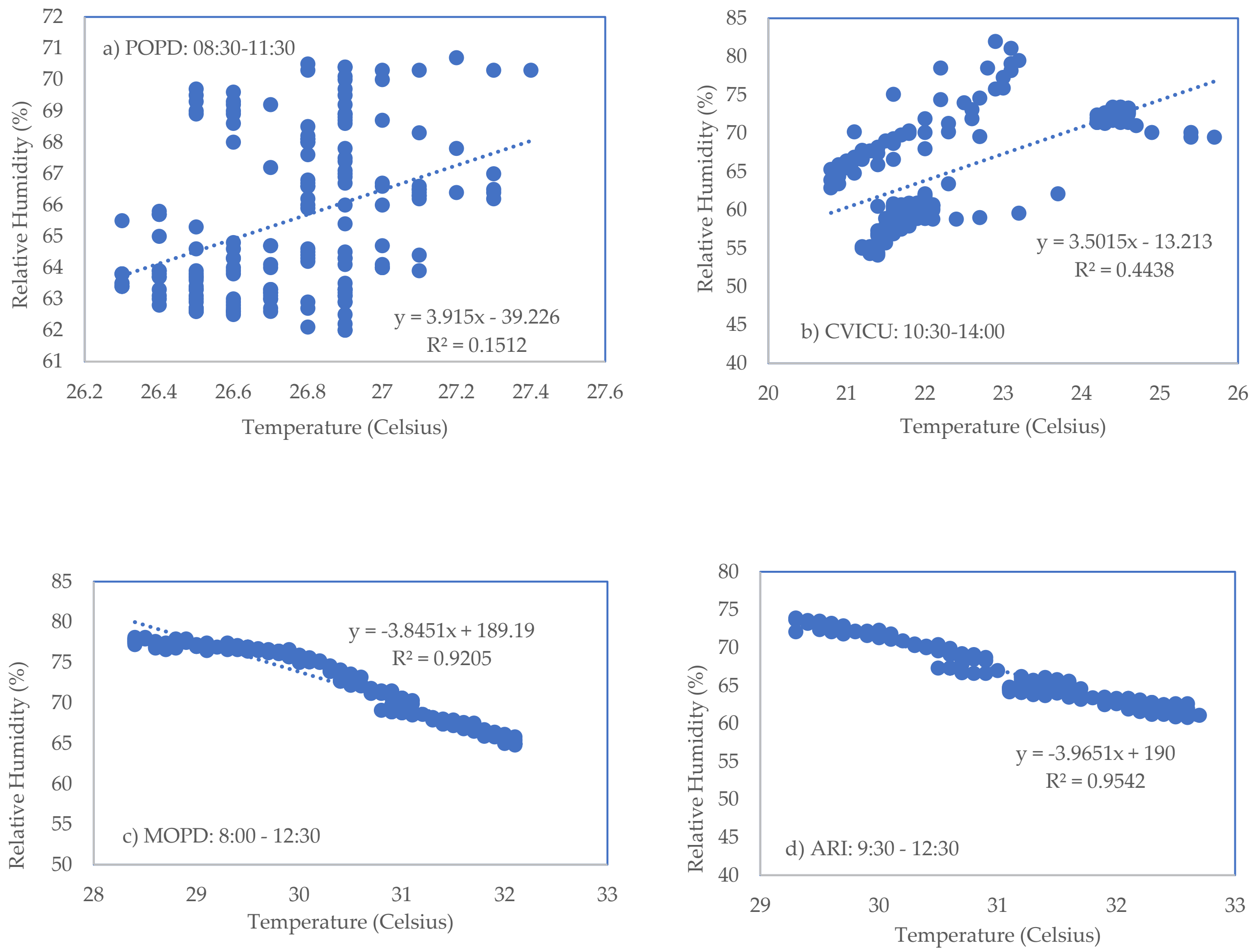

Figure 1: The relationship between temperature (Celsius) and relative humidity (%) in all sampling locations

CVICU and ARI had the same room ventilation rate, but the ventilation systems were different, and POPD had the lowest rate. The probability of Covid-19 infection from patient to healthcare personnel was quite low in the outpatient department, while the CVICU and ARI had a higher probability (Table 3).

The results of the occupational health exposure assessment are summarized in Table 4. The CDI of POPD was the highest (81.77 cfu/kgs/day) while CVICU was the lowest (4.86 cfu/kgs./day). The overall HI for HCW in this study was higher than 1.0, when using the no threshold for inhalation RfC while it seemed to be a safe workplace when using the recommendation for bioaerosol in hospitals less than 50, 100, and 500 cfu/m^3 except POPD.[16,17,25]

Table 3: The probability of infection and general characteristics of service areas of a tertiary care hospital

	General characteristic		**The probability of infection**			
	Ventilation system	**Total bacteria (cfu/m³)**	**Inconclusive Covid-19 cases per week**	**Confirmed Covid-19 cases per week**	**Q (m³/h)**	**Probability of infection***
POPD (n=19)	Mechanical ventilation with an Air Handling Unit	1837.46±132.32 (95%CI: 1777, 1901)	0	0	1,058	0
MOPD (n=18)	Mechanical ventilation with wall fan	618.37±14.84 (95%CI: 610, 626)	0	0	1,231	0
ARI (n=31)	Dilution ventilation	690.22±16.59 (95%CI: 684, 696)	1	19.29±10.67	1,337	1.0
CVICU (n=37)	Mechanical ventilation with a Negative pressure	263.44±125.66 (95%CI: 221, 305)	1.80±0.84	5.86±1.86	1,498	0.998±0.002 (95%CI: 0.998, 0.999)
Total (n=105)	-	-	-	-	-	0.65±0.48 (95%CI: 0.55, 0.74)

*Calculation based on the generation rate[33,34] of infection quanta (q) was 300 h^{-1}

Table 4: The occupational health exposure assessment, HQ and HI for healthcare workers

Parameter	**POPD (n=18)**	**MOPD (n=17)**	**ARI (n=29)**	**CVICU (n=37)**
CA (cfu/m³)	1837.46±132.32	618.37±14.84	690.22±16.59	263.44±125.66
IR (m³/hour)	0.83	0.83	0.83	0.83
ET (hour/day)	8.37±0.60	9.00±0.97	8.52±0.63	8.63±0.79
EF (day/week)	5.24±0.54	5.56±0.70	5.42±0.56	5.47±0.73
ED (year)	18.33±10.23	18.24±12.01	18.38±11.95	8.24±5.99
BW (kgs.)	57.67±9.78	58.89±7.70	59.21±17.23	54.89±9.67
AT (day)	13,870	13,870	13,870	13,870
CDI (cfu/kgs/.day)	81.77±43.95 (95%CI: 95.91, 103)	29.55±18.48 (95%CI: 20.04, 39.05)	33.25±22.04 (95%CI: 24.87, 41.63)	4.86±3.81 (95%CI: 3.59, 6.13)
Hazard Quotients (HQ)				
-No Threshold [a]	81.77±43.95 (95%CI: 95.91, 103)	29.55±18.48 (95%CI: 20.04, 39.05)	33.25±22.04 (95%CI: 24.87, 41.63)	4.86±3.81 (95%CI: 3.59, 6.13)
Hazard Index (HI) for HCW (n=101)	30.87±35.25 (95%CI: 23.91, 37.83)			
-50 cfu/m³ [b]	1.64±0.88 (95%CI: 1.20, 2.07)	0.59±0.36 (95%CI:0.40, 0.78)	0.67±0.44 (95%CI:0.50, 0.83)	0.10±0.08 (95%CI:0.97, 0.12)
Hazard Index (HI) for HCW (n=101)	0.62±0.71 (95%CI: 0.48, 0.76)			
-100 cfu/m³ [c]	0.82±0.44 (95%CI: 0.60, 1.04)	0.30±0.18 (95%CI: 0.20, 0.39)	0.33±0.22 (95%CI: 0.25, 0.41)	0.05±0.04 (95%CI: 0.04, 0.06)
Hazard Index (HI) for HCW (n=101)	0.31±0.35 (95%CI: 0.24, 0.38)			
-500 cfu/m³ [d]	0.16±0.08 (95%CI: 0.12, 0.21)	0.06±0.04 (95%CI: 0.04, 0.08)	0.07±0.04 (95%CI: 0.05, 0.08)	0.01±0.01 (95%CI: 0.01, 0.0)

Parameter	POPD (n=18)	MOPD (n=17)	ARI (n=29)	CVICU (n=37)
Hazard Index (HI) for HCW (n=101)		0.06±0.07 (95%CI: 0.05, 0.08)		

Remarks: CDI = chronic daily intake, CA = concentration of bioaerosols, IR = inhalation rate, ET = exposure time, EF = exposure frequency, ED = exposure duration, AT = average lifetime, BW = body weight (kg); a means no threshold for bioaerosol, b-d means recommendation for bioaerosol in hospital should be less than 50, 100 and at 500 cfu/m^3, respectively.[16,17,25]

Discussion

Environmental Status of SARS-CoV-2 Service Areas in Songklanagarind Hospital

Working conditions in the hospital, especially indoor air quality, are important because of the closed space having inadequate ventilation. Therefore, pathogens are accumulated inside the hospital. The hospital had various ventilation systems with air handling units (AHU), mechanical ventilation, dilution ventilation, and negative pressure. The concentrations of bacterial bioaerosol were lowest in the CVICU with negative pressure ventilation, while the POPD had the highest concentration with AHU. In addition, CVICU and ARI had similar room ventilation rates with clean air, but in ARI the general ventilation system had bacterial concentration higher than CVICU by approximately two-fold because CVICU had negative pressure ventilation. A similar finding that negative pressure ventilation in hospitals was effective in reducing airborne concentrations of pathogens has been reported earlier.[35] The ventilation system provides sufficient ventilation in such areas. In general, a well-functioning ventilation system provides temperature and humidity conditions that lower biological viability.[36,37] The bacterial bioaerosol concentration in MOPD (618.37±24.9 cfu/m^3) was less than in POPD (1,837.46±177.52 cfu/m^3), approximately 3-fold so because MOPD had higher room ventilation rate than POPD. Furthermore, previous studies have shown that SARS-CoV-2 is found on surfaces of an air exhaust outlet, in air filters, and building ducts of hospitals with COVID-19 patients.[35,36] To reduce the risk of SARS-CoV-2 transmission, the ventilation system could be maintained with cleaning at regular intervals and replacement of filters. The ventilation rates should be designed with appropriate recirculation of air. The bacterial bioaerosol concentrations in this study (259.72-1,837.46 cfu/m^3) are lower than in earlier reports from the Republic of Srpska (35-6,295 and 30-6,295 cfu/m^3), but higher than in previous reports from Iran (127-1,783 cfu/m^3) and from Taiwan (1-423 cfu/m^3) due to various factors, such as season, room design, ventilation system, temperature, relative humidity, work shift, type of ward, disinfection, and the numbers and activities of patients, visitors, and healthcare workers.[22,24,25,37]

The Probability of Infection and Determination of Covid-19 Infections via Bacterial Concentrations

To find out the relationship between ventilation system type by using indoor airflow and the probability of infection of HCWs (who move around their service area), the Wells-Riley model was used in this study.[32] The number of infectious individuals (*I*) was calculated from the weekly number of Covid-19 patients who visited a doctor during the sampling period. Therefore, the probability of infection rates was high at the Covid-19 service areas when using 300 h^{-1} for the quantum generation rate for SARs-CoV-2.[33,34] Then the probability of infection by airborne transmission of SARS-CoV-2 virus approached 1 in the suspected (ARI) and confirmed Covid-19 (CVICU) patient service areas, while the probability of infection approached 0 in the routine outpatient departments of the hospital. Even if there were no sufficient evidence that the SARS-CoV-2 virus can be transmitted by Heating, Ventilation, and Air Conditioning (HVAC) systems, the ventilation system of suspected and confirmed Covid-19 patient service areas should be considered for improvement.[37]

SARS-CoV-2 are enveloped positive-stranded RNA viruses with the RNA packaged within an outer fatty or lipid membrane and require host cells. Patients with COVID-19 have co-infections with bacterial pathogens such as *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Stenotrophomonas maltophilia*.[12,13,14,15] In this study, we determined the occupational (health) risk assessment via bacterial concentrations, and the CDI was lowest at CVICU that had a negative pressure room. This result was consistent with the risk level falling to a minimum when the maximum levels of filtration, maintenance and sanitizing in an HVAC- system are established.[9] However, the bacterial pathogens should be identified in the next study for a complete occupational exposure assessment of the HCW.

The occupational exposure assessment in hospital areas showed that overall, the hospitals' HI >1.0, indicating that bacterial bioaerosol may affect healthcare workers' health. The inhalation of RfC in a hospital should be as low as possible to protect patients and HCWs. To decrease the airborne virus transmission indoors, the hospital design could include room isolation, open halls, air conditioning units, and negative pressure rooms combined with hospital management policies, including wearing a sealed mask by patients, their relatives, and HCW, hand washing with alcohol, use of disinfectants for surface cleaning, assessments of body temperature, patient screening, and isolated acute respiratory infection clinic.[32,37,38,39] However, there was no question of wearing a mask of HCW in this study. According to the hospital policy, all HCWs have to wear and seal their mask during the working period.

This study was limited due to health risk assessment was measured from bacteria aerosol, and did not assess from SARS-CoV-2. Several studies have failed to collect viable SARS-CoV-2 in air samples. Sampling of airborne viruses is technically challenging for many reasons, including the limited effectiveness of some sampling methods for capturing fine particles, viral dehydration during collection, viral damage due to impact forces (leading to loss of viability), and viral retention in the sampling equipment.[40] The results may be used as a basis for preventive work for HCWs from Covid-19 Infection in hospitals. Although the results are based on health risk assessment from bacteria concentration, they do provide interesting points for future investigations, and also the health risk assessment from SARS-CoV-2 concentration needs further studies.

Conclusions

The probability of SARS-CoV-2 infection via bacterial concentrations for an HCW was high at suspected and confirmed Covid-19 patient service areas. The negative pressure room showed the lowest HI. The highest bacterial contamination and HI exceeding 1 was with the poorest room ventilation employing an AHU system. The inhalation RfC for hospitals should be as low as possible to protect patients and HCWs. Therefore, to control the SARS-CoV-2 airborne transmission indoors in a hospital, patient screening for separation of Covid-19 patients from other patients and ventilation system management adhering to standards, especially in room ventilation rates, should be pursued.

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