Indoor Air Quality in Public Health Centers: A Case Study of Public Health Centers Located on Main and Secondary Roadsides, Bangkok

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ABSTRACT

This cross-sectional study investigated the indoor air quality (IAQ) of public health centers (PHCs) and primary health care units in Bangkok to determine the impact of the different locations and ventilation systems concerning IAQ. Three indoor air pollutants: $PM_{2.5}$, CO_2, and CO were measured in three areas (medical record departments, outpatient departments and examination rooms) of six PHCs located in two different locations (main and secondary roadsides). The results showed that the average levels of $PM_{2.5}$, CO_2, and CO in the PHCs located on main roadsides were higher than those located on secondary roadsides. Among these parameters, only CO was found to significantly differ between those two locations indicating the result of vehicles and traffic sources regarding indoor CO level. Furthermore, all parameters were compared among the sampling areas with different ventilation systems; natural ventilation and air conditioner with and without ventilation fan. The amounts of all three pollutants significantly differed in each area with different ventilation systems. The average levels of $PM_{2.5}$ and CO_2 were the highest in areas with air conditioner without ventilation fan, while the level of CO was the highest in areas with natural ventilation. The ventilation was proved to be a key measure to improve IAQ. PHCs should consider ventilation efficacy to improve the IAQ by using ventilation fans in rooms using air conditioners. Finally, the average levels of all parameters were found below the recommended values in related standards, indicating safe IAQ for people working and receiving services in PHCs.

1. INTRODUCTION

Indoor air quality (IAQ) is one of the environmental risks concerning people's health, affecting their comfort and well-being when occupying a building (Luksamijarulkul et al., 2019). Currently, most people spend more than 90% of their time in various activities in indoor environments such as in an office, school, and their residence (Giulio et al., 2010). Thus, IAQ has become an important environment issue, especially in workplaces. Poor IAQ could lead to discomfort and sickness, and result in decreased work performance decrease and absenteeism in the workplace (Indoor Air Quality Management Group, 2019). Some equipment in buildings such as heaters, ventilation systems and air conditioners could cause high accumulation of air pollutants resulting in low IAQ (Brickus et al., 1998).

Public health centers (PHC) have roles and responsibilities to provide health services covering primary health care needs of people in Bangkok. Currently, 69 PHCs are distributed in 50 district areas in Bangkok to support convenient health services and reduce patient crowding in hospitals. In 2019, the monthly average number of patients totaled 2,423 (~80 people daily) depending on the service area of each center (Office of Public Health System Development, 2020). Moreover, PHCs are workplaces having strict requirements about IAQ because these places serve patients with communicable diseases who could spread pathogens through air transmission, so

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these places always use disinfectants inside the building (Hellgren et al., 2008). Thus, controlling IAQ remains an important role to prevent the spread of infectious diseases and protect hospital personnel and sensitive patients (Leung and Chan, 2006).

The location of the PHC is an important factor for patients to receive services, especially, PHCs located midtown on main roadsides that are easy to approach, and always receive many people requesting services. However, location has been found to be related to the potential sources of pollutants, such as busy roads, that affect the IAQ (Karner et al., 2010). A related study reported that people residing, working or attending school near major roads appeared to be at greater risk of a variety of short and long term health effects (Mullen et al., 2011). In Bangkok, major sources of air pollution include large numbers of vehicles, construction of buildings and sky train facilities, and open burning, especially grilling food using charcoal. Vehicles were indicated to be the main cause of air pollution problems in 2018; they generate high concentrations of pollutants including black smoke, nitrogen dioxide (NO_2), ozone gas (O_3), particulate matter with a diameter of 2.5 micrometers or less ($PM_{2.5}$), and particulate matter with a diameter of 10 micrometers or less (PM_{10}) causing problems in areas near roadsides (PCD, 2019).

Related research of IAQ in nine advanced level hospitals from 11 provinces in 2014 revealed that a high percentage of examination rooms from all hospitals exceeded the maximum permissible levels of air quality parameters, including CO_2 (15.59%), relative humidity (43.48%), temperature (87.68%), $PM_{2.5}$ (1.70%), formaldehyde (19.51%), bacteria (50.00%), and mold (25.75%) (Chokwinyou et al., 2014). More recently, a study measuring IAQ in Thailand concluded that the most problematic parameters included temperature, relative humidity and dust (PM_{10}, $PM_{2.5}$) due to activities of building users and insufficient ventilation (BOED, 2018). In addition, the Environmental Sanitation Office, Bangkok Metropolitan Administration conducted a survey to measure air quality in 27 buildings of PHCs in 2019 and found IAQ parameters in waiting rooms, OPDs and nursing laboratories of several PHCs were above the maximum permissible levels, including $PM_{2.5}$ (18.52% of total survey), PM_{10} (16.05% of total survey), and CO_2 (12.35% of total survey) exceeding the Singapore recommended values of less than 35 $\mu g/m^3$, 50 $\mu g/m^3$, and less than 1,000 ppm, respectively (Office of Public Health System Development, 2020).

This study aimed to reveal the IAQ of PHCs (involving three main parameters: $PM_{2.5}$, CO_2, and CO) located in different locations, main and secondary roadsides, which were compared to determine the effect of both locations on the IAQ. Results were also compared among different indoor areas to reveal the effect of ventilation on IAQ. The results can provide information to establish guidelines or suggestions to improve IAQ minimizing the health risk of the patient and staff in PHCs.

2. METHODOLOGY

2.1 Study area

This cross-sectional study was conducted in six of a total 69 PHCs in Bangkok from May to July, 2021 during the COVID-19 outbreak. These six sampling sites were selected using purposive sampling method and dividedg in two groups; three PHCs (PHC_A, PHC_B, and PHC_C) located on main roadsides, and another three PHCs (PHC_D, PHC_E, and PHC_F) located on secondary roadsides (small streets with two lanes) (Figure 1).

2.2 Data collection

In each PHC, samples were collected at three different areas including the medical records department (MRD), outpatient department (OPD), and examination room (EXR) hosting different activities, numbers of people and ventilation systems. Each sampling point was collected at two different service time intervals: 8.00 to 11.30 and 12.30 to 16.00. Triplicate samples were collected from three different weekdays; Monday, Thursday and Friday. For each sampling time, the three main parameters measured were $PM_{2.5}$, CO_2, and CO, and ventilation in the area was recorded while sampling. The sample sizes totaled 108 samples per parameter.

2.3 Indoor air quality measurement

The level of $PM_{2.5}$ was determined using a particle measurement instrument (DustTrak™ II Aerosol Monitor 8530). The instrument showed real-time aerosol mass readings with gravimetric sampling and zero calibration performed with a zero (HEPA) filter, before starting the sampling. The measurement ranged from 0.001 to 400 $mg/m^3$and particle size range was approximately 0.1 to 10 µm. CO and CO_2 were measured using an indoor air quality meter (HD37AB1347). The measurement range was 0 to 5,000 ppm for CO_2 and 0 to 500 ppm for CO. Both instruments were calibrated before initiating this study. For each measurement, the instruments were placed in the breathing zone at a height of 90 to 100 cm above the floor and in the middle of the room.

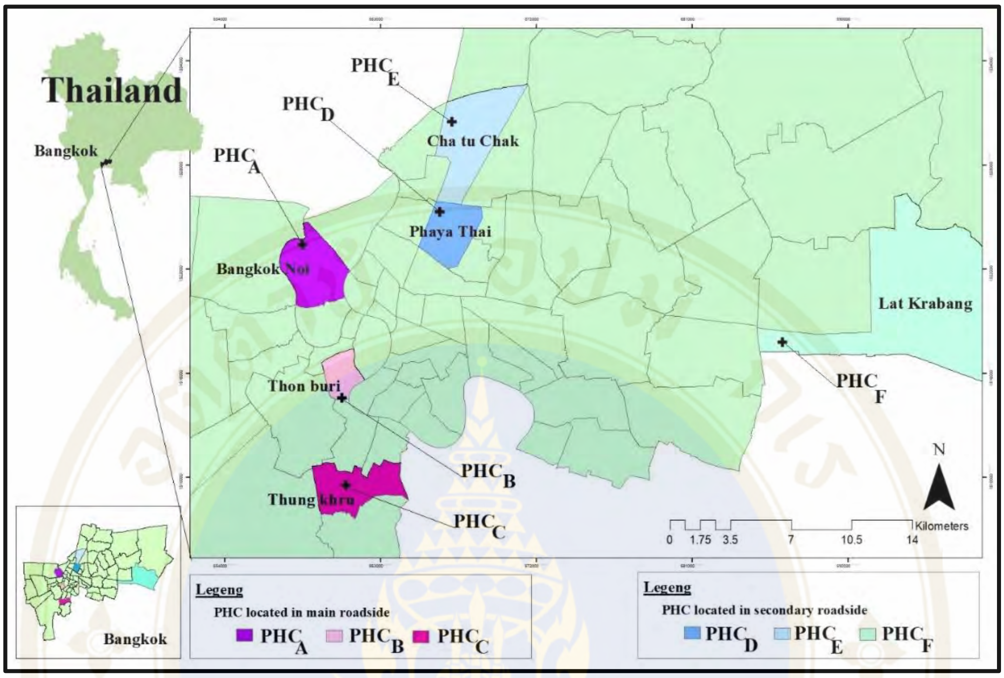

Figure 1. Map of sampling sites, Public Health Centers in Bangkok, Thailand

2.4 Statistical analysis

Descriptive statistics were used to illustrate PHC characteristics. The normal distribution of the results was checked using the Kolmogorov-Smirnov test, and each sample was assumed to be drawn from a non-normal distribution. The results obtained for IAQ parameters ($PM_{2.5}$, CO_2, and CO) were compared using the Mann-Whitney U test for different locations (main and secondary roadsides). The Kruskal-Wallis Test was used to compare the results of all measurements between different ventilations (natural ventilation, air conditioners without ventilation fan and air conditioners with ventilation fans). The critical level for statistical significance was used as $p<0.05$ and all data were analyzed using SPSS, Version, 18.0.

3. RESULTS AND DISCUSSION

3.1 Ventilation of the sampling areas in PHCs

In the selected PHCs, all the buildings were up to 30 years old. The sampling areas used different ventilation systems during sampling although they were located in the same type of sampling area: MRD, OPD or EXR. Most had air conditioners (83.3%) but some areas in some PHCs had natural ventilation provided by windows and doors (16.7%). Ventilation systems of the sampling areas could be divided in three types: natural ventilation, air conditioner without ventilation fan and air conditioner with ventilation fan as shown in Table 1.

Table 1. Ventilation systems of the areas during sampling (N=108)

Type of ventilation	Sampling area			Total (%)
	MRD	OPD	EXR	
Natural ventilation	0	7	11	18 (16.7%)
Air conditioner without ventilation fan	31	14	22	67 (62.0%)
Air conditioner with ventilation fan	5	15	3	23 (21.3%)
Total	36	36	36	108 (100%)

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3.2 Comparison of IAQ between groups of PHCs with different locations

The IAQ in two groups of PHCs, located on main and secondary roadsides were compared to investigate the effect between those locations on IAQ in PHCs and the result are shown in Table 2. The average levels of $PM_{2.5}$, CO_2, and CO in the PHCs located on main roadside were higher than those located on secondary roadside which proved that these different locations had an effect on IAQ in PHCs. However, only the CO was found to differ significantly between these two groups ($p<0.05$); the CO in PHCs on the main roadside was higher due to the higher traffic volume which was the main source of CO from the road. Babayiğit et al. (2014) reported in a case study of IAQ at primary schools in Turkey that the higher level of CO in schools located on a main street and close to heavy traffic significantly differed from the level in schools far from heavy traffic. However, Chamseddine et al. (2019) studied the indoor CO level from three hospitals in Beirut, Lebanon and found that the CO level at the lower floor was slightly higher than those at the upper floor primarily from the result of outdoor vehicle induced emission.

3.3 Comparison of IAQ in the sampling areas with different ventilation systems

To investigate the effect of ventilation on IAQ, the results of $PM_{2.5}$, CO_2, and CO measurement in each sampling area among three different ventilation systems were compared as shown in Table 3. The results of all $PM_{2.5}$, CO_2, and CO significantly differed in each area with different ventilation systems ($p<0.05$) indicating effect of ventilation systems on these indoor pollutants.

Table 2. Comparison of IAQ parameters in PHCs between the groups located on the main and secondary roadside

IAQ Parameter	Location of PHC		p-value
	Main roadside, (n=54)	Secondary roadside, (n=54)	
$PM_{2.5}$ (µg/m^3)	10.4±5.1	9.0±3.0	0.12
CO_2 (ppm)	777.0±290.1	668.4±119.4	0.13
CO (ppm)	2.5±1.4	1.6±0.8	<0.001*

*: Mann-Whitney U test

Table 3. Comparison of IAQ parameters among sampling areas in PHCs with different ventilation systems

IAQ parameter	Type of ventilation			p-value
	Natural ventilation, (n=18)	Air conditioner without ventilation fan, (n=67)	Air conditioner with ventilation fan, (n=23)	
$PM_{2.5}$ (µg/m^3)	9.4±3.3	10.5±4.7	7.7±2.6	0.034*
CO_2 (ppm)	538.3±62.0	793.1±253.6	662.0±94.8	<0.001*
CO (ppm)	2.5±0.9	2.2±1.4	1.2±0.6	0.001*

*: Kruskal- Wallis Test

For $PM_{2.5}$, the highest average level was found in area with air conditioners without ventilation fan (10.5±4.7 µg/m^3), following by natural ventilation (9.4±3.3 µg/m^3) and air conditioner with ventilation fan (7.7±2.6 µg/m^3), respectively. The highest average level in the area with air conditioner without ventilation fan was due to the accumulation of fine particles from outdoor sources such as diesel vehicles with no or less ventilation to the outside. However, the ventilation fan proved to reduce $PM_{2.5}$ level in the area with air conditioner. Lomboy et al. (2015) studied the characterization of $PM_{2.5}$ in an urban tertiary care hospital in the Philippines and found that the level of $PM_{2.5}$ in the mechanically ventilated wards were predominantly affected by the air conditioning system, human activities and the infiltration of contaminated outdoor air. Furthermore, a case study in Bangkok regarding the relationship between indoor and outdoor $PM_{2.5}$ concentrations in different conditions (open and closed ventilation systems) reported the $PM_{2.5}$ concentrations in the closed ventilation area in each place in terms of Indoor/Ambient ratio (I/A ratio) ranged from 0.37 to 3.57, indicating that outdoor $PM_{2.5}$ can enter the buildings through the ventilation system and infiltration (Sompornrattanaphan et al., 2018). Similarly, indoor $PM_{2.5}$ concentrations in noncentral air-conditioned hospitals were reported to be associated with outdoor concentrations indicating the impact of ambient air quality in urban centers on IAQ (Nimra et al., 2021). Lee et al. (2020) studied the intervention effect on IAQ in hospitals and found that only $PM_{2.5}$ concentrations decreased in rooms employing an air-cleaner. However, the highest average level of $PM_{2.5}$ at 10.5±4.7 µg/m^3 in this study was still below 15 µg/m^3 (24-hours) following the new WHO air quality guidelines (WHO, 2021) indicating low risk from $PM_{2.5}$ exposure inside the PHC building.

For CO_2, the highest average level (793.1±253.6 ppm) was found in the area with air conditioner without ventilation fan followed by air conditioner with ventilation fan (662.0±94.8 ppm) and natural ventilation (538.3±62.0 ppm). High CO_2 levels were detected in some areas, the maximum level at 1,708 ppm, which was higher than 1,000 ppm, indicating inadequate ventilation in the building (NIOSH, 1987). The source of indoor CO_2 was from people inside the building, both patients and staff under inadequate ventilation of the area resulting in indoor CO_2 accumulation. The natural ventilation via door and window openings proved to be the best choice to reduce indoor CO_2 effectively. Furthermore, appropriate outpatient appointment systems limiting and distributing the patient number during service times can be applied to reduce occupant density and time patients spent in the room. An onsite measurement of indoor CO_2 in the outpatient waiting rooms at a Chinese hospital revealed that CO_2 level varied with people density and measured CO_2 concentration exceeded the threshold of 1,000 ppm in hospital departments that were too crowed and during rush hour period (Tang et al., 2020). However, a related study of indoor CO_2 in another hospital in China, found that the cause of indoor CO_2 level related to patient habits to maintain thermal comfort including closing and opening windows or doors and turning the air-conditioner on and off. Increasing indoor CO_2 level resulted from the closed rooms where indoor air could not be diluted by fresh air from outside (Zhou et al., 2015). Similarly, Argunhan and Avci (2018) evaluated IAQ of the university classrooms in Turkey and found that increased CO_2 levels were associated with the number of people in the area together with closing doors and windows. However, Zuraimi et al. (2007) studied the effect of ventilation strategies of child care centers on IAQ in Singapore and found that the ventilation rates of the air conditioners were significantly lower than those of natural ventilation resulting in higher levels of occupant-related pollutants such as CO_2. In addition, the highest average level of CO_2 at 793.1±253.6 ppm was still below the threshold limit value of 5,000 ppm as the American Conference of Governmental Industrial Hygienists standard (ACGIH, 2013) indicating low risk from CO_2 exposure inside the PHC buildings.

For CO, the highest average level in the area with natural ventilation was 2.5±0.9 ppm, followed by air conditioner without ventilation fan (2.2±1.4 ppm) and air conditioner with ventilation fan (1.2±0.6 ppm). The highest average level in areas with natural ventilation was due to the outdoor source affecting IAQ. Ventilation fans were proven to reduce CO in the area with air conditioners. Mendes et al. (2013) studied the IAQ in elderly care centers in Portugal and found that maximum CO level was in the room with an open window next to a heavily trafficked road. Similarly, Synnefa et al. (2003) investigated the IAQ in 15 school buildings in Athens, Greece and found that CO level in several classrooms was higher than the recommended limits due to insufficient natural ventilation and lack of mechanical ventilation. However, the highest average level of CO at 2.5±0.9 ppm was still below the threshold limit value of 25 ppm (8 h) as the ACGIH standard (ACGIH, 2013) indicating low risk from CO exposure inside the PHC building.

Finally, an overview of the results in Table 3 revealed that better ventilation could provide better IAQ by reducing indoor air pollutants. Areas using air conditioner with ventilation fan had lower levels of $PM_{2.5}$, CO_2, and CO comparing with those areas without ventilation fan. Thus, ventilation fan openings in room using air conditioners should be employed to reduce health risks from indoor air pollutants. For the areas using natural ventilation, all three parameters were also determined in safe levels for people's health. However, the results in this study were from a survey in a short period which did not represent conditions all the year round, especially during the peak period of $PM_{2.5}$ in winter. Thus, the long term study covering the peak period is of interest for the further study.

4. CONCLUSION

Safety and health of staff and patients from $PM_{2.5}$, CO_2, and CO when working and receiving services in PHCs was ensured by the results in this study. Although all average levels of $PM_{2.5}$, CO_2, and CO were higher in PHCs located on the main roadside, only CO significantly differed between both locations

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which could indicate the sources from vehicle and traffic outside the buildings have an effect on the IAQ. However, comparing IAQ among three different ventilation systems, the average levels of all measured parameters in the area with different ventilation systems significantly differed indicating the effect of ventilation on indoor air pollutants. Ventilation was proved to be a key measure to improve IAQ. For this reason, PHCs should consider ventilation efficacy to improve the IAQ by using ventilation fans in rooms using air conditioners during service times.

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