

The Determinants of Mass Concentration of Indoor Particulate Matter in a Nursing Home

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Abstract. The study was conducted to evaluate the determinants of mass concentration of indoor particulate matter in a nursing home located in Taichung, Taiwan. PM_{2.5}, PM₁₀, temperature, relative humidity, CO, CO₂, O₃ and colony counts were collected in 2 bedrooms and their adjacent outdoor environments from November 2009 to January 2010. The results of multiple regression analysis suggested that the explanatory variables which included outdoor particle concentrations, indoor occupancy, different types of activities and ventilation accounted for 40.9% and 63.4% of the variance in the indoor PM_{2.5} concentration in Room A which is close to neighboring buildings and Room B which is close to main traffic, respectively. The explanatory variables accounted for 49.1% and 85.5% of the variance in the indoor PM₁₀ concentration in Room A and B, respectively. Moreover, the result of correlation analysis showed that both indoor PM_{2.5} and PM₁₀ concentrations were correlated to temperature, relative humidity and CO.

Introduction

To maintain people's health and quality of indoor living environment, "Recommended Indoor Air Quality Value" was publicly announced by EPA, Taiwan in 2005. The announced parameters include CO₂, CO, HCHO, TVOC, bacteria, fungi, PM_{2.5}, PM₁₀, O₃ and temperature. Particulate matter (PM), as one of the indicators to quantify the air quality of Taiwan [1], has been reported to have harmful effects on human health. Higher blood pressure and increased heart rate have been proved to be associated with indoor particles [2]. PM₁₀, referred to particles of 10 µm or less in aerodynamic diameter, can deposit in the bronchi and lungs and have been demonstrated to cause lung disorders, respiratory and cardiovascular diseases [3]. PM_{2.5}, referred to particles of 2.5 µm or less in aerodynamic diameter, tends to penetrate the alveoli in the lungs and has been shown to significantly correlated with cardiopulmonary disease and lung cancer [3].

Indoor particles can be generated from both indoor and outdoor sources. Indoor sources include use of combustion devices and indoor activities such as walking, children playing, cleaning, cooking, smoking, religious practice of incense burning and mosquito coil incense burning etc. [3, 4,

5, 6, 7]. Moreover, infiltration of outdoor particles and tracked-in materials such as soil organics and pet dander produced by human and animal activities also contribute to indoor particle concentration [3, 7]. The results of past researches have shown the major factors governing indoor particle concentration. Nevertheless, those studies were conducted mostly at residential, educational and commercial space. Therefore, the study aimed to investigate the determinants of indoor particulate concentration in healthcare space where the standard of cleanness aims higher. Moreover, in order to get better control of indoor air quality, the study was to investigate the relationships between indoor particulate matter and the parameters of announced indoor air quality value.

Key objectives of the research were:

1. to evaluate the determinants of mass concentration of indoor particulate matter;
2. to explore the relationships between indoor particulate matter and the measured parameters.

Experimental methods

Site description. Residents in nursing homes are mostly elderly who suffer from chronic diseases with weaker immune system. More than half of them are physically restrained on bed when they are awake. Therefore, the investigation of the determinants of indoor particulate concentration is beneficial in maintaining residents and caregiver's health. The study was conducted in a nursing home located in Taichung County, Taiwan. In order to investigate the relationships between indoor and outdoor particulate levels, Room A which is close to neighboring buildings and Room B which is close to main traffic (Fig. 1) were selected. The dimensions of Room A are 8.2m(L) x 5.1m(W) x 3m(H), giving the space volume of 125.46 m³. The dimensions of Room B are 11.6m(L) x 3.4m(W) x 3m(H), giving the space volume of 118.32 m³. The number of beds in Room A and Room B are 8 and 6, respectively.

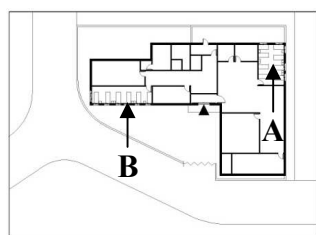


Fig. 1, Location of Room A & B

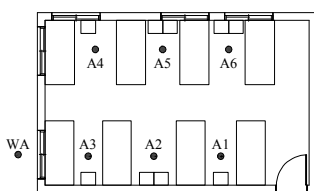


Fig. 2, Sampling points in Room A

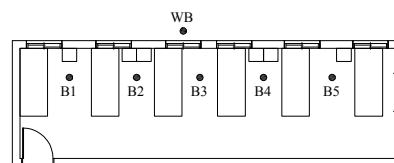


Fig. 3, Sampling points in Room B

Measuring Parameters. The selection of the measuring parameters was based on the parameters of "Recommended Indoor Air Quality Value." Since the interior decoration capacity of the nursing home is low, HCHO and TVOC were excluded in the study. Bacteria and fungi were replaced by colony counts. Relative humidity was included due to the indoor climate conditions is one of the contribution of indoor air quality. Therefore, the measuring parameters of the study included PM_{2.5}, PM₁₀, temperature, relative humidity, CO, CO₂, O₃ and colony counts. Other parameters taken into account were the weather conditions, indoor occupancy, indoor activities and room ventilation.

Sampling methods. Two portable aerosol particulate monitors (Aerocet 531/Met One) were used to monitor PM_{2.5} and PM₁₀. Both of these aerosol samplers were factory calibrated before the sampling test. The samplers were operating at a flow rate of 0.1cfm with 2 minutes sample interval. Indoor and outdoor PM_{2.5}/PM₁₀ samples were concurrently collected between 9:00am to 11:30am,

once every two weeks from November 2009 to January 2010. The inlet of indoor particulate sampler was set at 90cm above floor (as the level of the breathing zone of a lying nursing home resident) and 90cm from the wall (to avoid disturbing residents) between each bed in both rooms. The numbers of sampling points in Room A were 6 and in Room B were 5 (Fig. 2&3). Due to the site accessibility, the inlet of the outdoor particulate sampler for Room A was set at 110cm above floor and 60cm from window A (Fig. 2), while the inlet of the outdoor sampler for Room B was set at 110cm above floor and 30cm from window B (Fig. 3). The parameters of temperature, relative humidity, CO, CO₂ and O₃ were monitored by AirBoxx/KD Engineering with 1 minute sample interval. Colony counts were sampled by MAS-100NT in 5 minutes sampling time in each sampling point. Agar used was BAP which contained 5% sheep blood. Petri-dishes were cultured in a 37 ° C incubator for 24 hours. Colony calculations were done afterward.

Results and discussion

Activities observed in the bedrooms of the nursing home could be divided into two categories. Activity 1 referred to activities with torso and hand movements only, such as standing, talking and nursing activities. Activity 2 referred to activities involved whole body movements, such as walking, nursing cart moving and wheelchair moving. The mean indoor PM_{2.5} and PM₁₀ concentrations in Room A were 4.9 and 23.0 $\mu\text{g m}^{-3}$, respectively. The corresponding mean outdoor levels were 9.8 and 27.8 $\mu\text{g m}^{-3}$, respectively. By contrast, the mean indoor PM_{2.5} and PM₁₀ concentrations in Room B were 6.4 and 22.0 $\mu\text{g m}^{-3}$, respectively. The corresponding mean outdoor levels were 6.2 and 17.8 $\mu\text{g m}^{-3}$, respectively. The higher outdoor PM levels in Room A could be caused by laundry devices and activities occurring in the laundry area where the sampler was placed.

Multiple regression analysis was carried out to evaluate the effect of outdoor concentration, indoor occupancy, activities and ventilation on those indoors, taking the indoor concentration as dependent variable and outdoor concentration, number of indoor people in lying state, number of indoor people in motion state, number of times of Activity 1 & 2 happened per minute, type of ventilation (fans on vs. fans off) as explanatory variables.

The adjusted R² value for PM_{2.5} concentration in Room A was .409, which suggested that 40.9% variation in the explanatory variables could be attributed to the indoor PM_{2.5} concentration in Room A (Table 1). Among the explanatory variables, number of people in lying state, number of people in motion state, number of times of Activity 1 & 2 happened per minute and ventilation showed significant impact on the indoor PM_{2.5} concentration ($p < 0.01$). Outdoor PM_{2.5} concentration did not show significant impact on the indoors. By contrast, 63.4% variation in the explanatory variables could be attributed to the indoor PM_{2.5} concentration in Room B (Table 3). Outdoor PM_{2.5} concentration, number of people in lying state, number of people in motion state and ventilation showed significant impact on the dependent variable ($p < 0.01$). However, activities did not show significant impact on the indoor PM_{2.5} concentration in Room B.

Moreover, the explanatory variables accounted for 49.1% of the variance in the indoor PM₁₀ concentration in Room A (Table 2). Among the explanatory variables, number of people in motion state, Activity 2 and ventilation showed significant impact on the indoor PM₁₀ concentration

($p < 0.05$). Outdoor PM_{10} concentration did not show significant impact on the indoors in Room A. By contrast, the explanatory variables accounted for 85.5% of the variance in the indoor PM_{10} concentration in Room B (Table 4). Outdoor PM_{10} concentration, number of people in lying state, number of people in motion state showed significant impact on the dependent variable ($p < 0.01$). Activities did not show significant impact on the indoor PM_{10} concentration in Room B, too.

The phenomenon of outdoor $PM_{2.5}$ and PM_{10} concentrations had not shown significant impact on those indoors in Room A could be due to the location of the outdoor air sampler which was in the laundry area of the nursing home, the only accessible outdoor space adjacent to Room A. In order to avoid noise disturbance, window A was constantly closed. Therefore, outdoor particle had no significant effect on the indoor particulate levels, even though the rest of the windows were always opened. On the contrary, all of the windows in Room B were always opened during sampling period for ventilation. As the result, outdoor particulate levels had significant impact on those indoors in Room B. Moreover, Activity 1&2 exhibited no significant impact on indoor $PM_{2.5}$ and PM_{10} concentrations in Room B. The reason could be caused by less activity observed in Room B compared to Room A during sampling period.

Table 1, Result of a multiple regression model of the association between indoor $PM_{2.5}$ concentration and outdoor $PM_{2.5}$ concentration, indoor occupancy, type of activities and ventilation in Room A

	B	Beta	t	P
Constant	.016		5.349	.000
Outdoor $PM_{2.5}$	-.001	-.012	-.187	.852
Lying state	-.003	-.578	-3.595	.000
Motion state	.000	-.207	-2.954	.004
Activity 1	-1.581E-5	-.229	-3.185	.002
Activity 2	5.766E-5	.202	2.927	.004
Ventilation	.006	.042	6.773	.000
Model	R=.658		Adjusted R^2 =.409	
	F=18.198		P=.000	

Table 3, Result of a multiple regression model of the association between indoor $PM_{2.5}$ concentration and outdoor $PM_{2.5}$ concentration, indoor occupancy, type of activities and ventilation in Room B

	B	Beta	t	P
Constant	-.024		-9.317	.000
Outdoor $PM_{2.5}$.913	.670	7.525	.000
Lying state	.007	.631	8.940	.000
Motion state	.002	.270	4.844	.000
Activity 1	-1.312E-5	-.097	-1.455	.148
Activity 2	3.013E-5	.018	.341	.734
Ventilation	-.007	-.552	-5.568	.000
Model	R=.806		Adjusted R^2 =.634	
	F=42.197		P=.000	

Table 2, Result of a multiple regression model of the association between indoor PM_{10} concentration and outdoor PM_{10} concentration, indoor occupancy, type of activities and ventilation in Room A

	B	Beta	t	P
Constant	.025		1.904	.059
Outdoor PM_{10}	.007	.035	.581	.562
Lying state	-.001	-.060	-.401	.689
Motion state	-.001	-.154	-2.377	.019
Activity 1	2.351E-5	.071	1.071	.286
Activity 2	.000	.244	3.807	.000
Ventilation	.019	.708	4.961	.000
Model	R=.715		Adjusted R^2 =.491	
	F=24.938		P=.000	

Table 4, Result of a multiple regression model of the association between indoor PM_{10} concentration and outdoor PM_{10} concentration, indoor occupancy, type of activities and ventilation in Room B

	B	Beta	t	P
Constant	-.025		-6.587	.000
Outdoor PM_{10}	.783	.691	8.576	.000
Lying state	.009	.350	8.174	.000
Motion state	.002	.147	4.135	.000
Activity 1	3.809E-6	.012	.295	.768
Activity 2	-6.996E-5	-.018	-.554	.581
Ventilation	-.002	-.055	-.647	.519
Model	R=.928		Adjusted R^2 =.855	
	F=141.620		P=.000	

Correlation analysis was used to examine relationships among indoor $PM_{2.5}$, PM_{10} , CO_2 , T, RH, CO , O_3 concentrations and colony counts. The result (Table 5) showed medium correlation between

indoor PM_{2.5} and RH ($r=.575$, $p<0.01$), low correlations between indoor PM_{2.5} and CO₂, T, CO and O₃ concentrations. Moreover, the result had demonstrated high correlation between indoor PM₁₀ and temperature ($r=.721$, $p<0.01$), medium correlation between indoor PM₁₀ and colony counts ($r=.609$, $p<0.01$), low correlations between indoor PM₁₀ and RH, CO concentrations. The results suggested that higher temperature and relative humidity were along with higher PM concentrations.

Table 5, Result of a Pearson correlation model of the association between indoor PM_{2.5}, PM₁₀, CO₂, T, RH, CO, O₃, colony counts

	PM _{2.5}	PM ₁₀	CO ₂	T	RH	CO	O ₃	colony counts
PM _{2.5}	1	.569**	-.353**	.326**	.575**	-.244**	.380**	-.020
PM ₁₀	.569**	1	.021	.721**	.203**	-.388**	.085	.609**

Conclusion

Air samples were collected in 2 bedrooms and their adjacent outdoor environments in a nursing home located in Taichung, Taiwan. The results of multiple regression analysis suggested that the explanatory variables which included outdoor PM_{2.5} concentrations, number of indoor people in lying state, number of indoor people in motion state, number of times of Activity 1 & 2 happened per minute, type of ventilation (fans on vs. fans off) accounted for 40.9% and 63.4% of the variance in the indoor PM_{2.5} concentration in Room A and B, respectively. The explanatory variables accounted for 49.1% and 85.5% of the variance in the indoor PM₁₀ concentration in Room A and B, respectively. The result of correlation analysis showed that both indoor PM_{2.5} and PM₁₀ concentrations were correlated to temperature, relative humidity and CO. A detailed study of why lower CO concentrations was along with higher PM concentrations should be carried out to have better understandings of indoor air quality.

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