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Characterization of Indoor Air Quality in Public Area of Taiwan

Chih Mei Chou[+]

The Department of Environment and Property Management, JinWen University of Science and Technology, New Taipei City, Taiwan.

Abstract. Taiwan is a densely populated area with high-rise buildings close to main traffic roads or industrial plants. People spend most of time a day at home, at work, or in some means transport. Since the seventies and oil crisis, energy-saving, measures led to a reduction in the ventilation of building. In addition, many building have materials and equipment that give off a variety of irritating and sometimes toxic fumes or dust. The control of indoor air quality (IAQ) has become more important. For this reason, Taiwan's Indoor Air Quality Management Act is taking effect in 2013. This study was aimed at discovering common indoor air pollution at public site from the northern Taiwan, and evaluating the dynamic of carbon dioxide (CO_2) concentration during working hours. Also we discussed the main effect factors on indoor air quality.
The results of the high carbon monoxide (CO) and PM_{10} concentration may be ascribed to emissions from vehicle exhaust resulting on high-traffic locations at shopping mall and hospital. The high levels of total volatile organic compounds (TVOCs) appear at post office that may be caused by mail machine and vehicle exhaust from outdoor air. Bacteria and fungi may be caused by outdoor pollutants and air conditioning systems. In addition, CO_2 concentrations above 1,000ppm indicate poor ventilation of the indoor environment and can be remedied by improving ventilation.

Keywords: IAQ, ventilation, carbon dioxide

1. Introduction

Taiwan is a densely populated area with high-rise buildings close to main traffic roads or industrial plants. People spend most of time a day at home, at work, or in some means transport. Since the seventies and oil crisis, energy-saving, measures led to a reduction in the ventilation of building. In addition, many building have materials and equipment that give off a variety of irritating and sometimes toxic fumes or dust. For example, wood-based composites and synthetic interior finish materials has caused indoor pollutions. The control of indoor air quality (IAQ) has become more important. For this reason, Taiwan's Indoor Air Quality Management Act is taking effect in 2013 [1]. The suggested IAQ measurements include CO_2, CO, formaldehyde (HCHO), TVOCs, bacteria, fungi, particulate matter (PM_{10} and $PM_{2.5}$), ozone (O_3) and temperature. The act targets public areas, such as schools, medical and government organizations, financial institutions, opera houses, hotels, post offices as well as public transportation platforms.

The pollutants that affect the indoor air quality come from a variety of sources. In a recent review, the sick building syndrome (SBS) is a major concern because of the many people potentially at risk. It was defined by the World Health Organization (WHO) as an excess of work related irritations of skin and mucous membranes and other symptoms, including headache, fatigue etc. in office [2]. The symptoms usually develop on the first day back at work after a break, often in the same afternoon, and can become severe in the evening and night after the people has left work. Wood et al. carried out 600 office workers in USA showed that 20% of the employees experience symptoms of SBS and most of them were convinced that this reduces their working efficiency [3].

[+] Corresponding author.
E-mail address: cmchou@just.edu.tw

This study was aimed at discovering common indoor air pollution at public site from the northern Taiwan, and evaluating the dynamic of CO_2 concentration during working hours. Also we discussed the main effect factors on indoor air quality.

2. Materials and methods

This study selected 4 public sites in Taipei city including shopping mall, hospitals, post office and kindergarten, and investigated their IAQ. The reported investigation data was collected during May to October of 2012. This study used a combination of "real time" and long term monitoring of the ambient indoor air. 24-hour measurements were carried out for CO_2, CO, HCHO, TVOCs, bacteria, fungi, PM_{10} and $PM_{2.5}$, O_3, temperature and humidity. Indoor air samples were collected from the breathing zone, about 1.5m above the floor. During sampling, indoor parameters, such as smokers, operation of air cleaner, heater, and number of occupants, were recorded.

CO_2, CO, temperature and humidity were recorded using AirBoxx at 1-min intervals throughout the sampling period. TVOC were measure by IAQRAE. Bacteria and fungi samples were collected by the portable air sampler for Agar Plates (Burkard) for 4 min onto an agar media in a pertri dish. The agar plates were kept below 4℃ by a portable freezer after sampling. The agar plates were brought to the laboratory immediately and then incubated for 48h at 35℃ and 25℃. After incubate, the number of colonies formed was counted. In addition, to measure particle concentration, PM_{10} was monitor by HAZ-DUST EPAM-5000. It is also a portable microprocessor-based particulate monitor suitable for indoor air quality investigations.

3. Results and discussion

3.1. Measurements of indoor air quality

The results of the IAQ investigation at 4 public sites are summarized in Table 1. CO concentrations at shopping mall and hospitals were found to exceed the limited value of 9ppm. The cause of the high CO concentration may be ascribed to emissions from vehicle exhaust resulting on high-traffic locations. The high PM_{10} levels at post office was also caused by outdoor air, while the high PM_{10} levels may be associated with air conditioning and high-traffic locations.

In general, CO_2 concentrations above 1,000ppm indicate poor ventilation of the indoor environment and can be remedied by improving ventilation [4]. In this study, all of public site were lower than limited value, but hospital and post office almost exceeded the Taiwan EPA's threshold. Because of air conditioning usually employs constant recycling based to save electricity in Taiwan, thus ventilation may be insufficient to lower indoor CO_2 levels when crowds gather indoors. TVOC concentrations exceeding the EPA's threshold of 0.56ppm occurred in post office, the high levels of TVOCs may be caused by mail machine and vehicle exhaust from outdoor air.

Bacteria and fungi levels that exceed the suggested threshold are a common IAQ problem among the investigated public sites. High bacteria levels may be caused by outdoor pollutants and indoor crowds. Other factors that can also affect indoor bacteria concentrations include the cleaning of air conditioning systems, disinfectant housekeeping, and control of the ventilation rate. In addition to indoor green plants, the majority of fungal sources that contribute to high indoor fungi levels may be in the surrounding outdoor area.

3.2. Dynamic of CO_2 concentration during working hours

Figure 1 show the 24-h average concentration of CO_2 at shopping mall, hospital, post office and kindergarten. As shown in Fig.1, the CO_2 concentration was extremely high during high resident's activities. For example, the shopping mall in Taiwan used to open at 11:00, the high CO_2 concentration level was appeared at rush hours (11:00 to 13:00). The abnormally high CO_2 concentration, max concentration of 817 ppm. CO_2 concentration is used as an indicator of air quality in HVAC system because carbon dioxide is a main fluid waste from occupants within building. Although carbon dioxide is not the only indoor-air pollutant, CO_2-based controls were proposed to maintain at adequately low CO_2 level.

Table 1: Results of IAQ investigations at 4 public sites

	Limited Value	Shopping Mall			Hospital			Post office			Kindergartens		
		Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
CO_2 (ppm)	1,000	341	817	471	312	778	462	402	932	689	309	524	458
CO (ppm)	9	3.0	9.1	4.1	0.9	9.6	4.3	0.2	2.1	0.7	ND	ND	ND
PM_{10} ($\mu g/m^3$)	75	16	36	23	10	58	24	19	85	58	16	40	28
TVOC (ppm)	0.56	ND*	ND.	ND.	0.10	0.40	0.30	0.30	1.80	1.50	ND	ND	ND
Fungi (CFU/m^3)	1,000	492	843	631	631	1,572	732	519	791	681	731	2,191	792
Bacteria (CFU/m^3)	1,500	412	735	582	472	932	631	493	701	571	712	1,421	629
Temp. (℃)	26-28	21	25	23	18.1	20.2	19.0	24	28	25	25	26	25
R.H. (%)	-	58	70	63	63.0	68.1	65.4	64.1	74.2	65.1	59	62	61

* ND mean not detectable

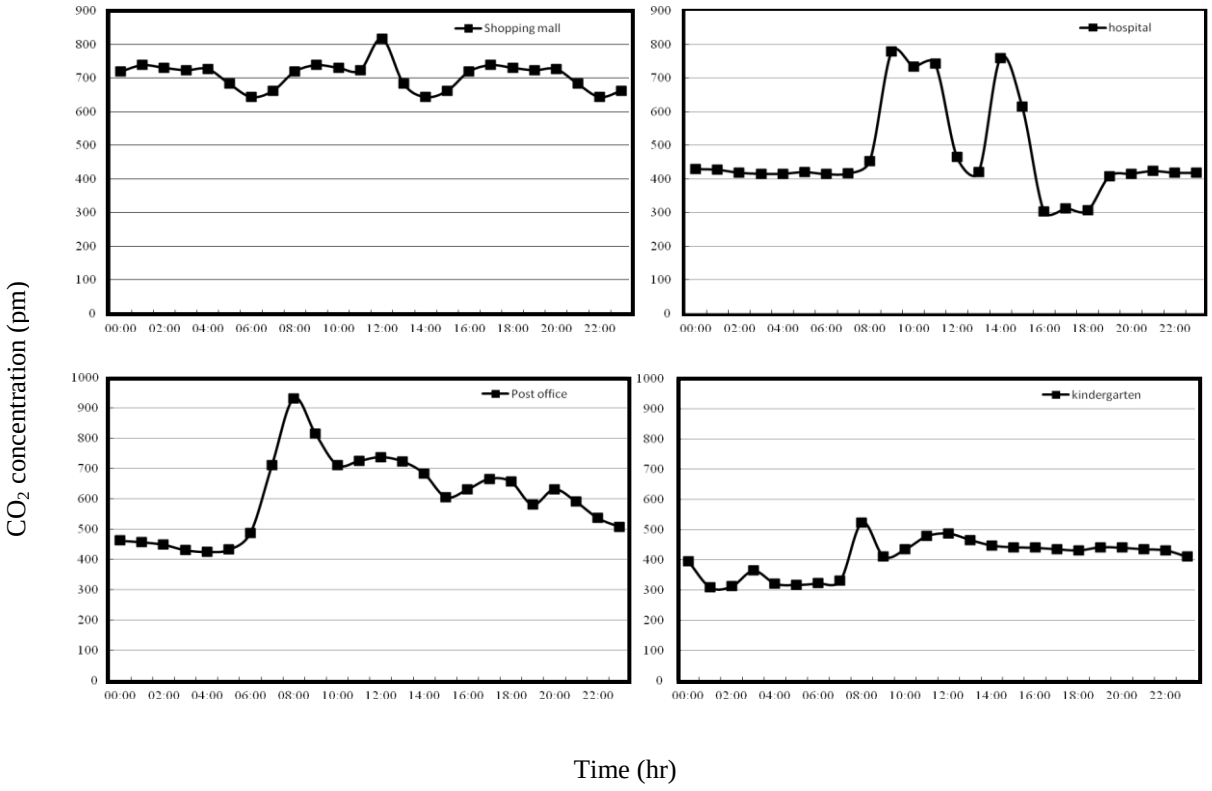

Fig.1: Dynamic of CO_2 concentration at 4 public sites

3.3. Effects factors on indoor air quality

Most of study shows that indoor air pollution affects IAQ and respiratory health. Air-conditioning systems and ventilation have frequently been singled out in research report as a major cause of SBS. In this study, we found out that main effect factors on indoor air quality.

- Temperature and relative humidity

Complaints about the temperature in buildings are common, particularly in those that are air conditioned. If the air is not circulated properly, different parts of the building might be too cold or hot. Air that is too warm is perceived to be stuffy and possibly polluted, whereas cool environments are regarded as being fresh. The standard for maintaining a certain acceptable level of comfort and occupational activity fluctuate between 20℃ to 26℃, a level of 50 to 70 percent should keep viral viability at a minimum. Some researchers indicated that temperature should be kept above in the lower part of the comfort range, because high temperature will increase off gassing from materials [5].

- Ventilation

The reference buildings were created to assess new technologies and support the development of energy codes and standards, and therefore their definitions are focused on capturing energy performance, not IAQ. Many discussions of building energy efficiency neglect potential impacts on IAQ or view acceptable IAQ as being in conflict with energy efficiency [6].

The ventilation can contribute by reducing the concentration of contaminants form building materials and processes within the building and also heat produced in the building. The most important measure to reduce such contaminants remains source control .

4. Acknowledgements

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