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Indoor Air Quality in a Cyber Café before and After the Amendments to the Tobacco Hazards Prevention Act in Taiwan

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ABSTRACT:

This study assessed differences in the indoor air quality and occupancy levels in a cyber café due to the amendments to the Tobacco Hazards Prevention Act (aTHPA) that took effect on January 11, 2009, in Taiwan. We measured the following in the selected cyber café before and after the smoking ban: CO_2 concentrations, fine particulate (PM_1) concentrations, mean number of occupants, and mean number of lit cigarettes. There were statistically significant changes in both CO_2 and PM_1 concentrations. Post-aTHPA air quality saw a 37.3% reduction in CO_2 and a 40.1% reduction in PM_1 compared to pre-aTHPA levels. This study suggests that the THPA must be enforced to effectively improve indoor air quality in cyber cafés in Taiwan. Maintaining a sufficient air exchange rate in closed-door cyber cafés is another important issue.

Keywords: Indoor Air Quality; Cyber Café; Smoking Ban

[I] INTRODUCTION

Environmental tobacco smoke (ETS) has been deemed a health hazard by various credible institutions [1]. Although Taiwan had already promulgated the Tobacco Hazards Prevention Act (THPA) as early as March 19, 1997, smoking was not prohibited in cyber cafés until amendments were made on January 11, 2009 [2]. Smoking bans such as this one are often controversial because owners of hospitality venues such as bars and restaurants claim to suffer economic losses due to a decline in patronage [3]. For cyber cafés in which patrons often smoke, it is up to the owners and operators of the cyber café to be mindful of the changes in indoor air quality (IAQ) due to smoking bans as well as the occupancy effects.

Researchers investigating the effects of smoking in hospitality venues (including bars, restaurants, and gaming areas in casinos) have determined that hospitality workers are exposed to relatively high concentrations of the indicator of ETS, nicotine [4-5], at concentrations that have been associated with substantial risks for heart and lung disease [6]. Studies have also pointed out that restaurants and pubs without designated smoking sections had elevated particulate matter

(PM_1 and $PM_{2.5}$) and nicotine concentrations [7-8], and that the presence of non-smoking sections reduced particle concentrations even in the smoking areas [9].

Ott et al. [10] measured respirable suspended particles (RSP) in a large tavern in Menlo Park, California, USA, and found a decline of 77–90% in RSP after the smoking ban. Mulcahy et al. [11] investigated the effectiveness of a total indoor smoking ban for all of Ireland and sampled nine pubs for $PM_{2.5}$ and PM_{10} levels in Galway City. The authors found a post-ban decrease of 75–96% for $PM_{2.5}$ concentrations and 47–74% for PM_{10} concentrations relative to pre-ban levels.

Carbon dioxide (CO_2) is frequently measured during IAQ evaluations to assess ventilation rates. An increase in CO_2 concentration is generally considered an indicator of inadequate fresh air supply. Humans are the main source of CO_2 through exhaled air, but unvented combustion processes and ETS may also contribute to CO_2 levels [12].

The present study was conducted to evaluate the effect of the amendments to the Tobacco Hazards Prevention Act (aTHPA) in Taiwan on indoor air quality by measuring indicators of ETS exposure in a cyber café in Pingtung County before and after the smoking ban took effect. The goal of this research was to provide information on the IAQ benefits of the ordinance to decision makers. Building occupancy measurements were also conducted and are intended to provide insight into potential economic impacts of the ordinance. The results contained herein will help concerned parties understand the effects of the aTHPA on cyber cafés.

[II] MATERIALS AND METHODS

2.1. Monitoring

The cyber café monitored was located at a non-urban area and had an interior volume of 326.1 m^3 and 37 seats (Figure 1). The monitoring activities were conducted half a month before the aTHPA took effect in autumn and 18 months after the aTHPA took effect in winter. Therefore, the door of the selected cyber café was not always closed during either monitoring period.

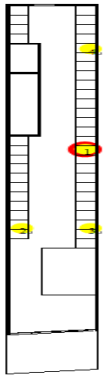

Figure 1: Layout diagram of the selected cyber café. Location of the monitoring instrument. Positions of the sampling sensors.

This study utilized an indoor pollution evaluation system (Model IES-2000; SIBATA Scientific Technology Ltd., Japan) to monitor and record the CO_2 and particulate matter (PM_1) concentrations in the selected cyber café. For each monitoring period, an indoor monitor was set up and concentrations were recorded every minute. Four sensors are distributed in the cyber café, and the heights of the sensors were 1.2−1.5 m, which covers a range near the human breathing zone. Automatic continuous monitoring of the cyber café was conducted for about 24 hours from 8:00 am to 8:00 am the following day. The number of occupants and number of lit cigarettes were counted every 15 min (at 0, 15, 30, and 45 min of an hour).

2.2. Data analysis

Descriptive statistics were calculated for the selected cyber café. The means and standard deviations of the CO_2 concentrations, PM_1 concentrations, occupants, lit cigarettes, and lit cigarettes per person were calculated separately for the pre-aTHPA and post-aTHPA periods. The minimum recorded value and maximum recorded value for each of the aforementioned variables were also determined. Finally, the percentage of measured CO_2 concentrations that met the

standard set by the Taiwan EPA for indoor air quality of 1000 ppm was determined [13]. Unpaired *t* tests were then performed to determine whether the CO_2 and PM_1 concentrations differed between the pre-aTHPA and the post-aTHPA periods in the selected cyber café.

[III] RESULTS

3.1. Descriptive statistics

The results from CO_2 sampling are summarized in Table 1. The minimum and maximum CO_2 concentrations measured in the pre-aTHPA period were 805 and 1178 ppm, respectively, with an average value of 950 ppm. Correspondingly, the minimum and maximum CO_2 concentrations measured in the post-aTHPA period were 485 and 1017 ppm, respectively, with an average value of 596 ppm.

All CO_2 measurements were compared with the IAQ standard of 1000 ppm. As shown in Table 1, the percentages of values recorded during the measurement meeting this criterion were 66.3% in the pre-aTHPA period and 99.5% in the post-aTHPA period, respectively.

Table 1: Results from CO_2 sampling

Monitoring period	Mean (ppm)	Minimum (ppm)	Maximum (ppm)	% < 1000 ppm
Pre-aTHPA	950	805	1178	66.3
Post-aTHPA	596	485	1017	99.5
Decline rate (%)	37.3*			

*$p < 0.001$; aTHPA = amendments to Tobacco Hazards Prevention Act.

The results from PM_1 sampling, occupancy levels, and number of lit cigarettes are summarized in Table 2. The minimum and maximum PM_1 concentrations measured in the pre-aTHPA period were $1.49X10^5$ and $2.96X10^5$ pt/cm^3, respectively, with an average value of $2.27X10^5$ pt/cm^3. Correspondingly, the minimum and maximum PM_1 concentrations measured in the post-aTHPA period were $6.94X10^4$ and $2.49X10^5$ pt/cm^3, respectively, with an average value of $1.36X10^5$ pt/cm^3.

The pre-aTHPA range of occupants was 3–43 people, and the post-aTHPA range was 1–22 people. The pre-aTHPA range of lit cigarettes was 0–5 cigarettes, and the post-aTHPA range was 0–3 cigarettes. Furthermore, the mean of lit cigarettes per person in the pre-aTHPA period was 0.04 cigarettes, while the mean of lit cigarettes per person was 0.06 cigarettes in the post-aTHPA period. Obviously, there were still occupants who did not comply with the ban.

Table 2: Cyber café information, including pre- and post-aTHPA PM_1 concentrations, number of occupants, lit cigarettes, and lit cigarettes per person

Statistics	PM_1 (pt/cm^3)	Occupants (no.)	Lit cigarettes (no.)	Lit cigarettes per person (no.)
Pre-aTHPA				
Min	$1.49X10^5$	3	0	0
Max	$2.96X10^5$	43	5	0.33
Mean	$2.27X10^5$	21	0.69	0.04
SD	$3.06X10^4$	12	0.88	0.07
Post-aTHPA				
Min	$6.94X10^4$	1	0	0
Max	$2.49X10^5$	22	3	0.33
Mean	$1.36X10^5$	10	0.56	0.06
SD	$4.19X10^4$	5	0.76	0.08
Decline rate (%)	40.1*	–	–	–†

*$p < 0.001$; †$p > 0.05$; aTHPA = amendments to Tobacco Hazards Prevention Act

3.2. The *t*-test analysis

Unpaired *t* tests were performed to determine whether the measured CO_2 and PM_1 concentrations, as well as the lit cigarettes per person values, were significantly different between the pre-aTHPA and post-aTHPA periods (Tables 1 and 2). The statistical results showed that the CO_2 and the PM_1 concentrations were both highly significantly different ($p < 0.001$), with the post-aTHPA measurements consistently recording lower CO_2 and PM_1 concentrations than the pre-aTHPA measurements. The declines

in the CO_2 and PM_1 concentrations were 37.3% and 40.1%, respectively. However, the *t*-test results for the lit cigarettes per person values showed no significant change ($p > 0.05$) in smoking frequency (or behavior) between the pre- and post-aTHPA periods.

[IV] DISCUSSION

This study analyzed the effects of the January 11, 2009 aTHPA on the occupancy levels, inhibition of smoking behavior, and indoor air quality for the selected cyber café in Pingtung, Taiwan. Our results were different from those of other researchers who concluded that a ban on smoking in hospitality venues does not appear to cause reductions in patronage [10-11, 14]. Although the results of this study show that the number of post-aTHPA patrons dropped about half compared to pre-aTHPA numbers (Table 2), this may be related to whether monitoring takes place on a weekend or weekday (pre-aTHPA monitoring was conducted on a Sunday, while post-aTHPA monitoring was conducted on a Wednesday) or due to changes in the economy or in consumer behavior. Therefore, these variations make it impossible for this study to prove that implementing the aTHPA lowered the number of cyber café patrons. Nonetheless, we are aware that the methods of occupancy sampling used here are less than ideal and may not represent a true account of the economic effects on cyber café owners.

Just as there may not be unquestionable evidence regarding the economic impacts of the smoking ban on cyber café owners, even the effects of the ban on indoor air quality are difficult to clarify. While there was less smoking after the ban, the number of cyber café patrons was also reduced. Comparing the average number of lit cigarettes per person, there was no significant difference between the pre-aTHPA and post-aTHPA periods. For the analyses of the pre- and post-aTHPA PM_1 data, there was a statistically significant reduction in PM_1 concentrations. This finding is consistent with other particulate measures for hospitality venues reported in other studies [8, 14-16], and is not surprising. The number of patrons and number of lit cigarettes both decreased during post-aTHPA monitoring; considering circumstances with no other pollutants, then, PM_1 concentrations would naturally be lower.

The mean CO_2 concentration was significantly higher in the pre-aTHPA period than in the post-aTHPA period ($p < 0.001$). This result is similar to that reported by Waring and Siegel [14]. Even if post-aTHPA CO_2 levels were only 0.54% of values recorded during the measurement over 1000 ppm, this may be related to the fact that the doors to the cyber café were normally opened, raising the air exchange rate. In summertime when doors were closed and air conditioning was turned on, increases in CO_2 concentrations must be noted.

This study found that 18 months after aTHPA implementation, non-urban cyber cafés are still unable to follow the regulations and stop patrons from smoking; this may be related to the fact that owners and operators of non-urban cyber cafés are more concerned with personal relationships. Naturally, this is also related to whether the governmental body behind the act indeed enforces it; however, these circumstances are inimical to the consequences of the amendments, and also make the improvements in IAQ unobvious.

[V] CONCLUSION

The results of this study indicate that differences exist between pre- and post-aTHPA cyber cafés in terms of air quality. The CO_2 and PM_1 concentrations were higher in the pre-aTHPA cyber café than in the post-aTHPA cyber café. After implementation of the aTHPA, cyber cafés with their doors normally opened still saw CO_2 concentrations over 1000 ppm. The average concentration (596 ppm) was also near 600 ppm (Taiwan EPA criteria for indoor air in schools/educational institutions). This is one area of particular concern for cyber cafés near schools,

as many of their patrons are students. Additionally, there are still patrons who smoke in cyber cafés; the average number of lit cigarettes per person showed no significant decrease compared to pre-aTHPA measures.

The results of this study indicate that patrons and owners and operators of non-urban cyber cafés do not abide by the amendments to the THPA. Inspections of cyber café owners and operators by the relevant authority on cyber cafés must be enforced before the aTHPA can effectively improve IAQ. In addition, non-urban cyber cafés are often established inside residences (like the cyber café in this study) where airflow and ventilation are not planned specifically for cyber café operation. In summary, in view of the aforementioned illegal smoking activity and poor air ventilation, this study suggests that the relevant authority on cyber cafés should strengthen inspections of illegal smoking in indoor cyber cafés and that the Taiwan EPA should test the IAQ in cyber cafés to implement the Indoor Air Quality Act [17] and ensure the physical health of the public.

FINANCIAL DISCLOSURE

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