การตรวจวัดฝุ่นละอองขนาดเล็กสำหรับประเมินการรับสัมผัสควันบุหรี่มือสอง: หลักฐานเชิงประจักษ์ที่มีส่วนช่วยในการออกกฎหมายปลอดบุหรี่

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บทคัดย่อ

นโยบายการควบคุมยาสูบของประเทศไทยได้ผลักดันให้มีการลดการรับสัมผัสควันบุหรี่มือสองเพื่อปกป้องสุขภาพผู้ไม่สูบบุหรี่มากว่า 20 ปีแล้ว ในการเสริมสร้างความเข้มแข็งแก่กฎหมายปลอดบุหรี่นั้น จะต้องมีหลักฐานเชิงประจักษ์ประกอบในการขับเคลื่อนภารกิจนี้ การศึกษานี้มีวัตถุประสงค์เพื่อตรวจวัดระดับของควันบุหรี่มือสองในสถานประกอบการหลายประเภท เพื่อดูลักษณะปัญหาคุณภาพอากาศภายในอาคารในประเทศไทย วิธีการเก็บตัวอย่างและวิเคราะห์ตัวอย่างฝุ่นละอองขนาดเล็ก ($PM_{2.5}$) ซึ่งเป็นตัวชี้วัดมลพิษจากควันบุหรี่มือสองนั้น ใช้วิธีการและอุปกรณ์ปรับเทียบมาตรฐาน ตามวิธีการที่ใช้ในโครงการสำรวจและตรวจสอบอากาศสากลที่ประเทศไทยเป็นส่วนหนึ่งของโครงการความร่วมมือนี้ มีการเก็บตัวอย่าง $PM_{2.5}$ จำนวน 53 ตัวอย่างจากสถานประกอบการต่าง ๆ เช่น ร้านอาหาร บาร์ สถานีขนส่ง ทั้งที่มีการสูบบุหรี่ (26 แห่ง) และไม่มีการสูบบุหรี่ (27 แห่ง) พบว่าค่าเฉลี่ยของ $PM_{2.5}$ ในสถานประกอบการที่มีการสูบบุหรี่เท่ากับ 319 ไมโครกรัมต่อลูกบาศก์เมตร และในสถานที่ที่ไม่มีการสูบบุหรี่ เท่ากับ 29 ไมโครกรัมต่อลูกบาศก์เมตร เมื่อเปรียบเทียบกับเกณฑ์มาตรฐานฝุ่นขนาดเล็กขององค์กรพิทักษ์สิ่งแวดล้อมสหรัฐอเมริกา พบว่าในสถานประกอบการที่มีการสูบบุหรี่นั้นค่าเฉลี่ยระดับฝุ่นขนาดเล็กเป็น 21 เท่าของค่ามาตรฐานเฉลี่ยตลอดปี (15 ไมโครกรัมต่อลูกบาศก์เมตร) และเป็น 9 เท่าของค่ามาตรฐานเฉลี่ย 24 ชั่วโมง (35 ไมโครกรัมต่อลูกบาศก์เมตร) ค่าเฉลี่ยสูงสุดของฝุ่นขนาดเล็กที่วัดได้ในบาร์คือ 488 ไมโครกรัมต่อลูกบาศก์เมตร ซึ่งเป็น 14 เท่าของค่ามาตรฐานเฉลี่ย 24 ชั่วโมง กระบวนการออกกฎหมายนั้นต้องอ้างอิงหลักฐานเชิงประจักษ์ พิจารณาทางเลือกในการแก้ไขปัญหา และสร้างกรอบของกฎข้อบังคับที่จะให้มีการปฏิบัติตามได้มากที่สุด ซึ่งผลการศึกษานี้แสดงให้เห็นว่าการวิจัยที่สนับสนุนนโยบาย สามารถส่งผลให้เกิดกลยุทธ์ในการตอบสนองต่อภาวะคุกคามทางสิ่งแวดล้อมที่สำคัญ เช่น การรับสัมผัสควันบุหรี่มือสอง ได้ทันสถานการณ์

คำสำคัญ: การรับสัมผัสควันบุหรี่มือสอง; ฝุ่นละอองขนาดเล็ก ($PM_{2.5}$); นโยบายสิ่งแวดล้อม; สถานประกอบการ; กฎหมายปลอดบุหรี่

Measuring Fine Particles to Assess Secondhand Smoke Exposure: Evidence Contributing to Smoke-free Regulation

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Abstract

Reducing exposure to secondhand smoke to protect the health of nonsmokers has been the central thrust of tobacco control in Thailand for 20 years. The strengthening of smoke-free regulation required producing evidence for this task. Our aim was to examine the levels of secondhand smoke in a variety of occupational settings to characterize the extent of the indoor air problem in Thailand. As part of a collaborative study, the Global Air Monitoring Survey, a standardized protocol and calibrated air sampling instrument, was used to collect and analyze samples of fine particles ($PM_{2.5}$), indicators of secondhand smoke pollution. Fifty-three samples of $PM_{2.5}$ were collected from workplaces such as restaurants, bars, and transportation stations, where smoking was present (26 venues) and where there was no smoking (27 venues). The mean level of $PM_{2.5}$ in establishments with smoking present was 319 micrograms per cubic meter, and 29 micrograms per cubic meter where there was no smoking. When compared to the US Environmental Protection Agency (EPA) particulate standards, the level in venues with smoking present was twenty-one times higher than the annual standard of 15 micrograms per cubic meter, and over nine times the 24 hour standard of 35 micrograms per cubic meter. The highest mean level was in bars, 488 micrograms per cubic meter, about fourteen times the 24 hour standard. Regulatory processes involve assessing existing evidence, examining alternative solutions, and building a regulatory framework that maximizes compliance. Our experience shows that policy supportive research activities can result in strategic steps to respond in a timely manner to an important environmental threat such as secondhand smoke exposure.

Keywords: Secondhand Smoke Exposure; $PM_{2.5}$; Environmental Policy; Workplace; Smoke-Free Regulation

Introduction

Regulatory controls on exposure to secondhand smoke in Thailand began with the restriction on smoking in theatres and on public buses by the Bangkok Metropolitan Authority in 1976. However, the more comprehensive regulation was the national Nonsmokers' Health Protection Act adopted in 1992. It provided for smoke-free areas in some locations and separate smoking and non-smoking areas in others (Supawongse, 2007). Despite the tobacco industry's disinformation campaign in Asia in the 1990s, the 1992 Act had already made it clear that smoking needed to be eliminated for the health of nonsmokers, and thus smoke-free areas were eventually to be extended to include all public areas (Barnoya & Glantz, 2005). This process began in earnest in 1997 with a review of the enforcement and effectiveness of the Act (Supawongse, 2007). In addition, research was done to characterize air quality levels in areas where protection was inadequate and where regulation needed to be strengthened (Charoenca et al., 2002). This resulted in a 2002 notification and many later notifications by the Ministry of Public Health, which extends the coverage of smoke-free areas to include nearly every public institution and all areas, such as pubs and bars and entertainment venues (Ministry of Public Health, 2002; Ministry of Public Health, 2010).

Fine particle pollution such as smoke and haze consists of very small solid particles and liquid droplets a fraction of the diameter of even a human hair, 2.5 micrometers in size. The small size of this particulate matter, which is the predominant particle pollution from the smoke from cigarettes or exhaled by smokers, is known as $PM_{2.5}$ (Levy, Wegman, Barron, & Sokas, 2011). Though other indicators have also been used, $PM_{2.5}$ is the most common and widely accepted indicator for assessing secondhand smoke exposure (SHS) from tobacco, also known as tobacco smoke pollution and other names (Ott, Steinmann, & Wallace, 2007). Particle pollution measured as $PM_{2.5}$ has been studied and linked to increased respiratory symptoms, decreased lung function, aggravated asthma, development of chronic bronchitis, irregular heartbeat, nonfatal heart attack, and premature death from heart or lung disease (American Lung Association, 2006). Environmental studies have linked $PM_{2.5}$ to various disease effects and

evidence-based standards for average annual and 24 hour exposure set at 35 and 15 micrograms per cubic meter by the U.S. Environmental Protection Agency (EPA) (United States Environmental Protection Agency, 2006).

Secondhand smoke has been known to be linked to lung cancer in adults since 1981, when a study of nonsmoking spouses of smokers in Japan showed clear evidence that lung cancer development by nonsmokers was associated with SHS exposure (Hirayama, 1981). This study has been followed by hundreds of studies and authoritative reviews of the evidence which show multiple disease effects from secondhand smoke in every system of the human body (US Department of Health and Human Services, 2006). These accumulating findings showing adverse effects are of greatest concern to women and children, who bear a heavy burden of severe and long-term consequences when exposed to secondhand smoke in the home or workplace. Those making efforts to reduce such exposures benefit from reviewing the success and limitations of progress in making smoke-free regulation work in various settings (Sarna, Bialous, Rice, & Wewers, 2009).

In this present study, as a part of the Global Air Monitoring Survey, a collaborative, multi-country research, $PM_{2.5}$ measures were monitored in various locations to characterize where exposures were greatest and what air quality benefits would accrue through smoke-free locations (Roswell Park Cancer Institute, 2006). This is important information that provides a contextual understanding of exposure levels in different places in Thailand.

The aim is to make an assessment of the levels of secondhand smoke by measuring air particulate matter of less than 2.5 microns in size ($PM_{2.5}$), commonly produced by smoking indoors. The assessment in this present study will show the air pollution levels in occupational settings where smoking is present and where it is not. The results will be compared to U.S. Environmental Protection Agency (EPA) Standards for particulates and how these results have been used as a baseline for more studies that have contributed to Thailand's regulatory commitment to smoke-free places.

Methods

A total of 53 samples of $PM_{2.5}$ were taken from various venues: restaurants, bars, transportation stations, hospitals, hotels, and offices (Table 1). The designations "Smoking" and "Smoke-free" places were given according to the smoking situation observed during the sampling period. The type of venues was selected according to the protocol established for the multi-country study so that the results could be compared to those of other participating countries (Hyland, Travers, Dresler, Higbee, & Cummings, 2008). Indoor air quality in all venues was measured for levels of respirable suspended particles (RSP) in the form of particulate matter in the air smaller than 2.5 microns in diameter ($PM_{2.5}$). These fine particles are produced in great numbers from burning cigarettes; thus they are used as a strong indicator of exposure to second-hand smoke (SHS) (Pope et al., 2002). Numerous large studies worldwide have used concentrations of $PM_{2.5}$ to assess SHS exposure in public places (Navas-Acien et al., 2004; Nebot et al., 2005; Stillman et al., 2007; Lopez etal., 2008; Hyland et al., 2008). SHS is not the only source of indoor particulate matter; however, smoking is by far the largest contributor to indoor particulate matter pollution.

At each venue, the concentrations of $PM_{2.5}$ were measured for 30 minutes using a battery-operated aerosol monitor (TSI SidePak AM510 Personal Aerosol Monitor, TSI Incorporated, Shoreview, Minnesota, USA), following an established protocol described by Hyland, Travers, Dresler, and others in 2008. The monitor was fitted with an impactor to measure $PM_{2.5}$. Each day before use, it was zero calibrated with a high efficiency particulate air filter according to the manufacturer's specifications. The device was set to record the real-time concentration of $PM_{2.5}$ in micrograms per cubic meter. The carry bag containing the SidePak monitor was placed on a table or bar at a height to ensure that the air sampled was as close as possible to the human breathing zone. The samples were collected by Thai researchers, and Roswell Park Cancer Institute staff in the US analyzed the data. Statistical significance was assessed using the Mann-Whitney U-test for the comparison of the smoking and smoke-free venues.

Table 1 Types of venue sampled for $PM_{2.5}$

Venue type	Number of smoking places	Number of smoke-free places	Total
Restaurant	5	17	22
Bar	15	0	15
Transportation	4	3	7
Other (hospitals, hotels, and offices)	2	7	9
Total	26	27	53

Results

The number and types of venues sampled in Thailand are shown in Table 1. Note that restaurants and bars were the most frequently sampled. At the time of the collection of data only air conditioned restaurants were required to be smoke-free and there was no smoke-free requirement in bars. Table 2 shows the average levels of $PM_{2.5}$ in restaurants, bars, transportation stations, and other venues such as hotels, hospitals and offices. In restaurants, average levels where smoking was present were more than four times those in smoke-free restaurants (131 versus 30 micrograms/cubic meter). In bars, the average level was extremely elevated—nearly fourteen times the US EPA standard for 24 hour $PM_{2.5}$ levels. The US EPA air quality index considers any particulate level over 250 micrograms/cubic meter as hazardous to health. In transportation stations and other venues, levels were significantly increased where smoking was present, though the levels were much lower both with and without smoking since these are locations where there is a much greater movement of people, with less time/opportunity for people to smoke.

Figure 1 compares all of the venues where $PM_{2.5}$ levels were recorded. Overall, the 27 smoke-free venues showed an average of 29 micrograms/cubic meter, below the US EPA 24 hour standard, while the average level where smoking was present was more than 9 times that standard at 319 micrograms/cubic meter. This hazardous overall air index average was primarily due to the extremely high levels in restaurants and bars, though transportation and other venues were also above the EPA 24 hour standard.

Table 2 Average $PM_{2.5}$ (micrograms per cubic meter) by types of venue

Venue Type	Restaurant		Bar	Transportation		Other (hospitals, hotels, and offices)	
Smoking situation	Smoking (n=5)	Smoke-free (n=17)	Smoking (n=15)	Smoking (n=4)	Smoke-free (n=3)	Smoking (n=2)	Smoke-free (n=7)
Average	131	30	488	58	36	38	23
Min-Max	15-337	7-78	34-1598	36-98	29-48	36-39	15-31

Note: The difference between smoking and smoke-free venues is statistically significant, $p<0.001$, according to the Mann-Whitney U-test.

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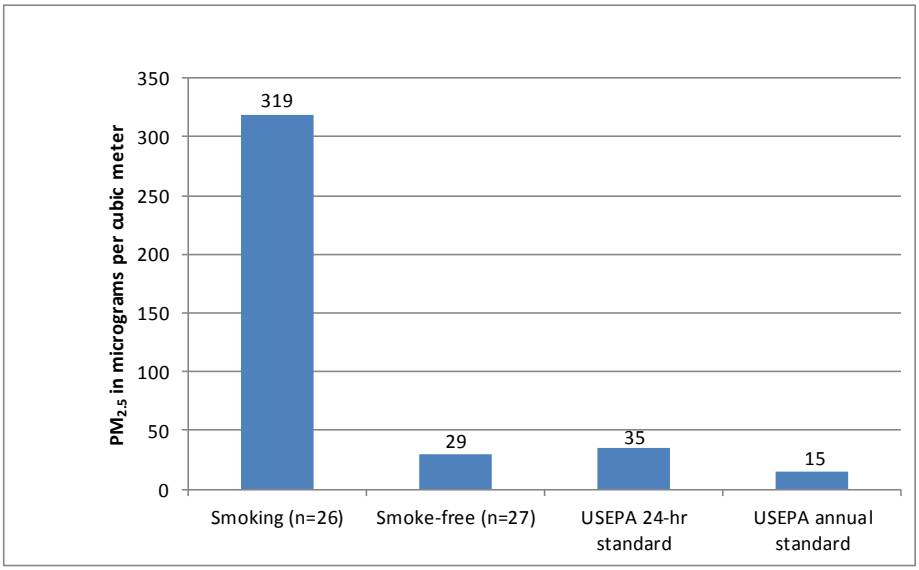

Figure 1 Average PM2.5 compared to the USEPA standards

Discussion

The results presented for Thailand mirror the findings produced years before in the United States when research was conducted to characterize the occupational levels of exposure to secondhand smoke in a variety of settings (Hammond, 1999). This research was conducted to define the size and scope of the problem in occupational settings. Because levels of exposure were found to be high in most settings in the US, various options for restrictions on secondhand smoke were considered, implemented and tested for efficacy. A review of those efforts shows that smoke-free places are low cost, safe and effective, and once implemented receive increasing public support (Erikson & Cerak, 2008). Thailand has been fortunate to have developed a clear focus on smoke-free regulations in its 1992 legislation since the worldwide progress on smoke-free public places and the increasing evidence of the harm of secondhand smoke exposure have made the need to eliminate exposure an important goal, especially for the health of vulnerable populations such as women and children. This reality, plus the growing understanding of the overall economic benefits of smoke-free places, has motivated Thailand to incrementally move forward with the extension of smoke-free regulations (Repace, Zhang, Bondy, Benowitz, & Ferrence, 2012). Some low- and middle-income countries are still struggling to get beyond the evidence of the dangers of secondhand smoke to a commitment to smoke-free places and to establish that commitment with strong regulation and enforcement (Erazo et al., 2010).

Our results have provided baseline findings for occupational settings and have been expanded through our additional research to provide more data which provides country-level evidence of the consequences of exposure to secondhand smoke. In 2002, we published a specific paper on secondhand smoke exposure levels in restaurants (Charoenca et al., 2002a). In quick succession through 2008, research followed on the dangers of secondhand smoke to children, exposure levels for youth, women, and children, in transportation stations, and for workers and patrons in pubs and bars (Charoenca, Kungskulniti, & Vichayanon, 2002b; Charoenca, Kungskulniti, Tipayamongkholgul, Lohchindarat, &Hamann, 2006; Hamann, Charoenca, Kungskulniti, Kengganpanich, Kin, & Travers, 2007a; Charoenca

et al., 2007; Charoenca, Kungskulniti, Lapvongwatana, Hamann, & Inkam, 2008a; Charoenca et al., 2008b). Thus, the importance of our results in characterizing the levels of secondhand smoke in restaurants, bars, transportation stations and other public locations is that it provides a platform for further characterization of indoor smoking as a very serious source of indoor air pollution, which needs to be addressed by stronger provisions of the Thai Nonsmokers' Health Protection Act. The results have been provided to public health officials in and outside the government so that the levels of exposure would be known, the dangers of those levels of exposure would be appreciated, and the policy implications of this information in light of regulatory responsibilities would be clear. From 2002 to 2010, the Ministry of Public Health made nine notifications which strengthened the smoke-free provisions to include all restaurants, pubs and bars, government buildings, transportation stations, educational and religious institutions, and healthcare facilities (Visarutwong, Sirirungruengamorn, Termsirikulchai, Kengkarnpanich, & Teskhayan, 2009).

Thailand's progress rests on the shoulders of research, which has provided not only an understanding of exposure levels but also of the population consequences in Asia. For example, the astonishing fact that more women in China die from lung cancer from secondhand smoke exposure than from smoking itself demonstrates the enormity of the problem in Asia (Gan, Smith, Hammond, & Hu, 2007). The consequences of secondhand smoke exposure for children are also a major concern in Asia (Lee et al., 2012). Research worldwide has shown that secondhand smoke exposure from smoking indoors results in both short- and long-term consequences that affect smokers and nonsmokers, families, communities, countries, and the wellbeing of society.

Conclusion

Our findings represent a platform for further investigation of the problem, alternative solutions, and the implementation of regulatory policy. They have sounded a drum beat that calls for health advisors and policy makers to push for additional smoke-free places in Thailand. This is an example of how policy-relevant research activities can be a central part of the path of policy analysis

and change (Bardach, 2009). Achieving smoke-free environments requires the strategic management of environmental resources in order to maintain adequate compliance levels where inspection and monitoring may be difficult. New approaches to address compliance with smoke-free regulations in difficult-to-monitor settings have been developed (Enander, Gagnon, Hanumara, Park, Armstrong, & Gute, 2007). Thus, research on secondhand exposure levels needs to continue to ensure that adequate compliance is achieved. Environmental specialists recognizing the importance of the high $PM_{2.5}$ levels found in Thailand must surely continue to support this work.

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