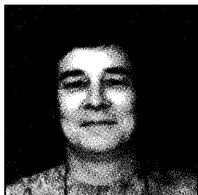


Hawai'i Air Quality Monitoring Assessment: Some Effects of Hawai'i's Smoke-Free Work and Public Places Law

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Abstract

In November 2006, the Smoke-Free Work and Public Places Law passed to protect people from secondhand smoke in Hawai'i. An air-quality monitoring assessment to determine the difference this law made in air quality was conducted at 15 bars/restaurants. Levels of particulate matter ($PM_{2.5}$) at enclosed (indoor) venues fell 90% after implementation of the law while partially enclosed restaurants/bars were all below the EPA 24 hour average limit both before and after the law.

Introduction

Secondhand Smoke and Smoking Prevalence in Hawai'i

The Environmental Protection Agency (EPA) and the US Surgeon General have concluded that prolonged exposure to secondhand smoke (SHS), also known as environmental tobacco smoke or indoor air pollution, presents a serious public health risk.¹⁻³

More than 17 years ago, Hawai'i passed a statute prohibiting smoking in most areas open to the public (e.g. workplaces) (Chapter 328K of the Hawaii Revised Statutes), and all counties subsequently adopted ordinances that offered varying levels of protection to workers and the public against SHS.⁴ The Hawai'i Legislature passed SB 3262 CD1 in May 2006 and Governor Linda Lingle signed Act 295 on July 10, 2006 making Hawai'i the 14th state to enact a strong smoke-free workplace law. This new law restricts smoking in all workplaces, including bars and nightclubs (previously exempted by the prior statute), and includes outdoor areas of bars, as well as enclosed or partially enclosed areas of buildings and public places.

The objective of the present air quality monitoring assessment was to assess any changes in air quality that occurred in a convenience sample of venues before and after implementation of the new law, statewide. However, it is important to note that Hawai'i provides a unique set of venues to test air quality since many restaurants and bars may be fully enclosed, while others may be only partially enclosed or have areas such as a *lanai*.⁵ Therefore, Hawai'i presents a distinctive opportunity to test air indoor quality at some fully enclosed venues, as well as partially enclosed venues (with varying degrees of ventilation).

Smoking Bans and Indoor Air Quality Assessment

Published studies have assessed the effect of statewide smoking bans on indoor air quality.⁶⁻⁸ Repace (2004) measured RSP particulate matter in six bars, one casino, and one pool hall in Delaware before and after their state-wide law went into effect, and Travers and colleagues (2004) assessed the change in air quality in 20 hospitality establishments before and after the implementation of the New York State Clean Indoor Air Act. They both reported dramatic reductions in RSP levels after the smoking laws took effect.

It is important to note that only a few studies to date have focused on assessment of the effects of smoking, secondhand smoke, and outdoor air quality.^{9,10} A recent study by Klepeis, Ott, and Switzer (2007) concluded that "...it is possible for outdoor tobacco exposure to present a *nuisance* or *hazard* under certain conditions of wind and smoker proximity" (*co-authors' emphasis*). It is important to point out that there is a difference in what could constitute a public health "nuisance" versus an actual public health "hazard".

Clearly much more research is needed in this area, especially since the present Hawai'i air-quality assessment included both enclosed sites without adequate ventilation and partially enclosed sites (with varying degrees of ventilation). In partially enclosed venues, it is likely that trade wind patterns and conditions throughout the state of Hawai'i could result in high overall air quality and high levels of ventilation. Therefore, in this assessment, along with the other measurements, the average temperature, average humidity, wind conditions and outdoor air quality were also reviewed during the testing dates and times, both prior to and after the implementation of the new law.

Methods

Monitoring the change in respirable suspended particles (RSPs) in restaurants/bars/clubs may be a useful tool to assess the effectiveness of smoking policies, since SHS is one source of RSPs.¹¹ RSPs, specifically a class of RSPs known as $PM_{2.5}$ (i.e. particulate matter less than 2.5 microns in diameter), are very small particles suspended in the air that pose health risks, since they can

easily be inhaled deep into the lungs,¹² and are useful markers for approximately 4000 compounds, of which 50 are carcinogenic. Because of their negative health effects, the EPA has instituted an outdoor standard for RSPs less than 2.5 microns ($PM_{2.5}$), consisting of an average annual $PM_{2.5}$ exposure level of $15 \mu\text{g}/\text{m}^3$ and a daily (24 hour average) exposure level of $65 \mu\text{g}/\text{m}^3$; this current study uses this standard.¹³

This assessment attempted to follow, as much as possible, the protocols and methodology of other SHS air quality monitoring studies conducted throughout the United States.¹⁴ Following such protocols, a minimum of 6-10 venues were selected, since several venues could be sampled in one evening and only require one or two individuals to conduct the testing. The sampling frame included a minimum of 3-5 establishments where smoking was allowed prior to the new law implementation (i.e. bars/nightclubs, pool halls, and restaurant/bars) along with a minimum of 3-5 smoke-free establishments (control sites). For Hawai'i, the sampling frame included sites that were both enclosed and partially enclosed. Since there were no available resources to conduct a standard study, aside from renting of the monitoring machine, volunteers from community tobacco coalitions were recruited to conduct the air quality monitoring tests and all took the online Air Monitoring Course prior to monitoring the venues.

Air quality was monitored using a TSI Sidepak AM510 Personal Aerosol Monitor¹⁵ to sample and record the levels of RSPs in the air (particulate matter with a mass median aerodynamic diameter less than $2.5 \mu\text{m}$, or $PM_{2.5}$). Particles of this size are referred to as "fine particles" and are released in large quantities from burning cigarettes and other sources of pollution such as car exhaust. As per the instructions, the SidePak device was calibrated to zero by Tobacco Prevention and Education Program staff prior to monitoring at both time periods (before and after the law). Two different Sidepak machines were used at the two time periods.

Volunteers were asked to place the SidePak in a convenient shoulder bag, computer case, or backpack and were asked to collect observational data during the air monitoring including descriptions of the venue(s) and any other pertinent observations (presence of no smoking signs, ashtrays, air filtration devices, fans or other ventilation, number of people in the venue, and number of burning cigarettes).¹⁶ After air monitoring was completed at selected venues, the SidePak was either provided to the next volunteer or returned to the Tobacco Prevention and Education Program. When the device was returned, the data were then downloaded to a computer to check that the data were recorded.

A total of 15 sites were monitored during Friday and Saturday evenings (between 7pm to 2am), before the law in late June/early July 2006 and after the law in late April/early May 2007. A different restaurant with similar characteristics was selected as an alternate site

in 2007 when a previous site closed during the interval period. The median length of time that the volunteers spent in the venues before the implementation of the ban was 42 minutes, and the range was from 30-60 minutes; after the implementation of the ban, the median length of time spent in the venues was 28 minutes with a range from 18 minutes to 49 minutes.

Results

The graphic results are displayed in Figures 1-4 for each island and the tabular data are summarized in Tables 1-3. The tabular data have been organized by the type of venue: enclosed, partially enclosed, or control sites. Prior to analysis, the first and last logged data points were removed and the remaining data points were averaged to provide the average concentration of $PM_{2.5}$ within each venue. The percentage change in $PM_{2.5}$ was calculated by comparing these averages before and after the law was implemented. The one outdoor smoking area was omitted from the statistical analysis (although it has been left on the graph). Two partially enclosed sites where smoking was allowed but not observed (pre-law) were treated as 'control sites'.

Regarding average temperature, average humidity, wind conditions, and outdoor air quality prior to and after the implementation of the new law (Table 1), there were no discernable differences found during the two different testing dates. Average particulate matter levels (based on $PM_{2.5}$ levels microgram per cubic meter: $\mu\text{g}/\text{m}^3$) before the implementation of the law were higher in enclosed venues than partially enclosed venues (Table 2). The range of reduction in $PM_{2.5}$ for enclosed venues was from 85.2% to 94.8%, with an overall average level reduction of 90.1%. For partially enclosed and control sites, the average levels of $PM_{2.5}$ below the average EPA 24 hour (daily) average limit. The particulate levels at partially enclosed and control sites increased after the implementation of the law (with an average of 19% increase in the partially enclosed sites and a 73.6% increase in the control sites), but all remained at levels below the average EPA 24 hour (daily) average limit despite the increase. The graphic results (Figures 1-4) illustrate the before and after effects of reduced particulate matter at enclosed venues, along with consistent low-level particulate matter at partially enclosed and control sites. Results were consistent on both O'ahu and on the neighbor islands.

Regarding cigarette density, smoker prevalence, and the average number of patrons (Table 3), before the law at the enclosed sites, the 3 gay-friendly venues (Sites 3, 4, and 5) showed the highest level of cigarette density and smoker prevalence. Regarding smoker prevalence, the enclosed bars had the highest levels, with the 3 gay-friendly venues (Sites 3, 4, and 5) and an enclosed bar on the Big Island (Site 7) having various smoker prevalence levels slightly higher than the state average of 17.5% (and ranging from 19.3%-26.6%) but with an

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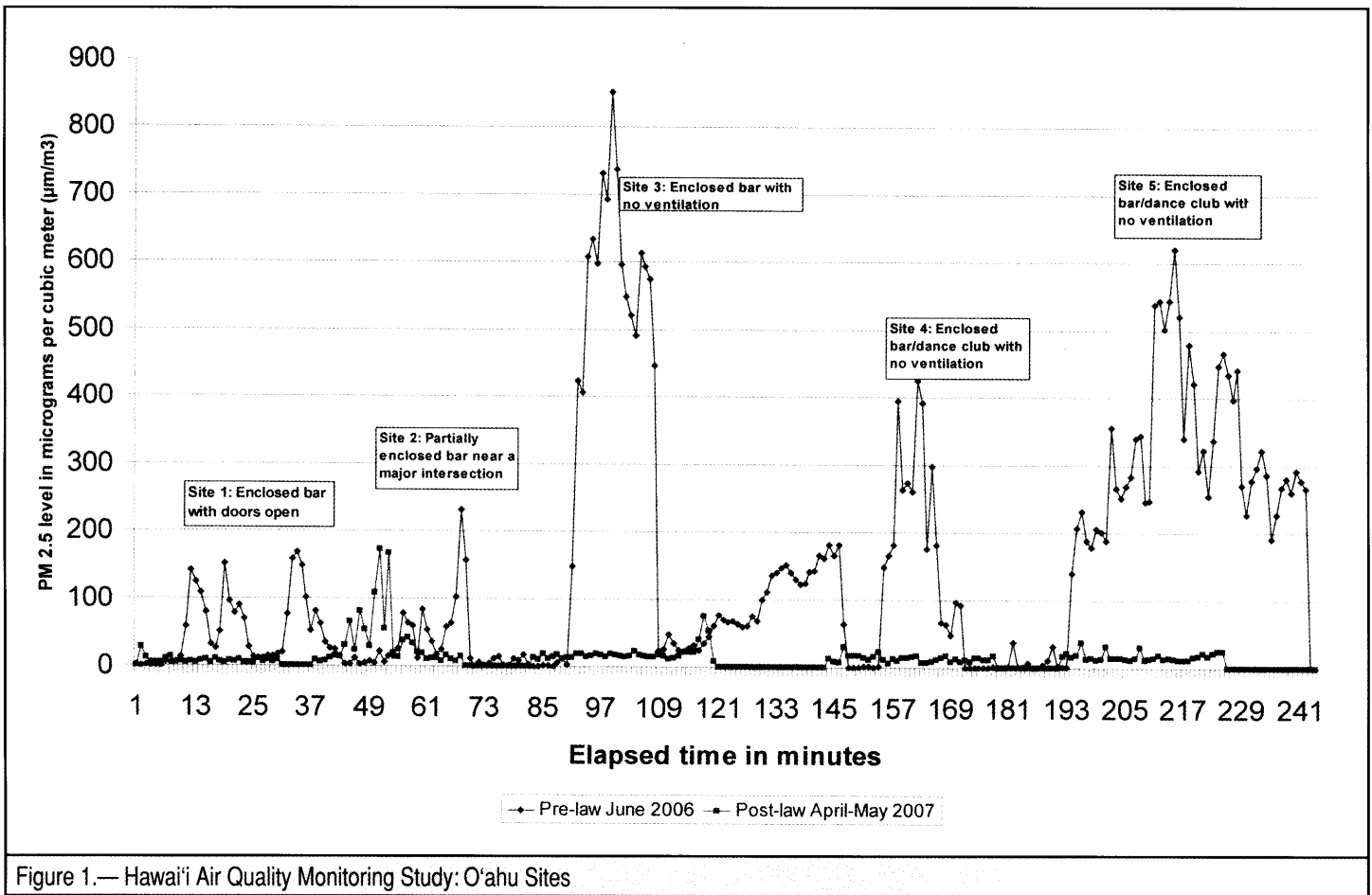


Figure 1.— Hawai'i Air Quality Monitoring Study: O'ahu Sites

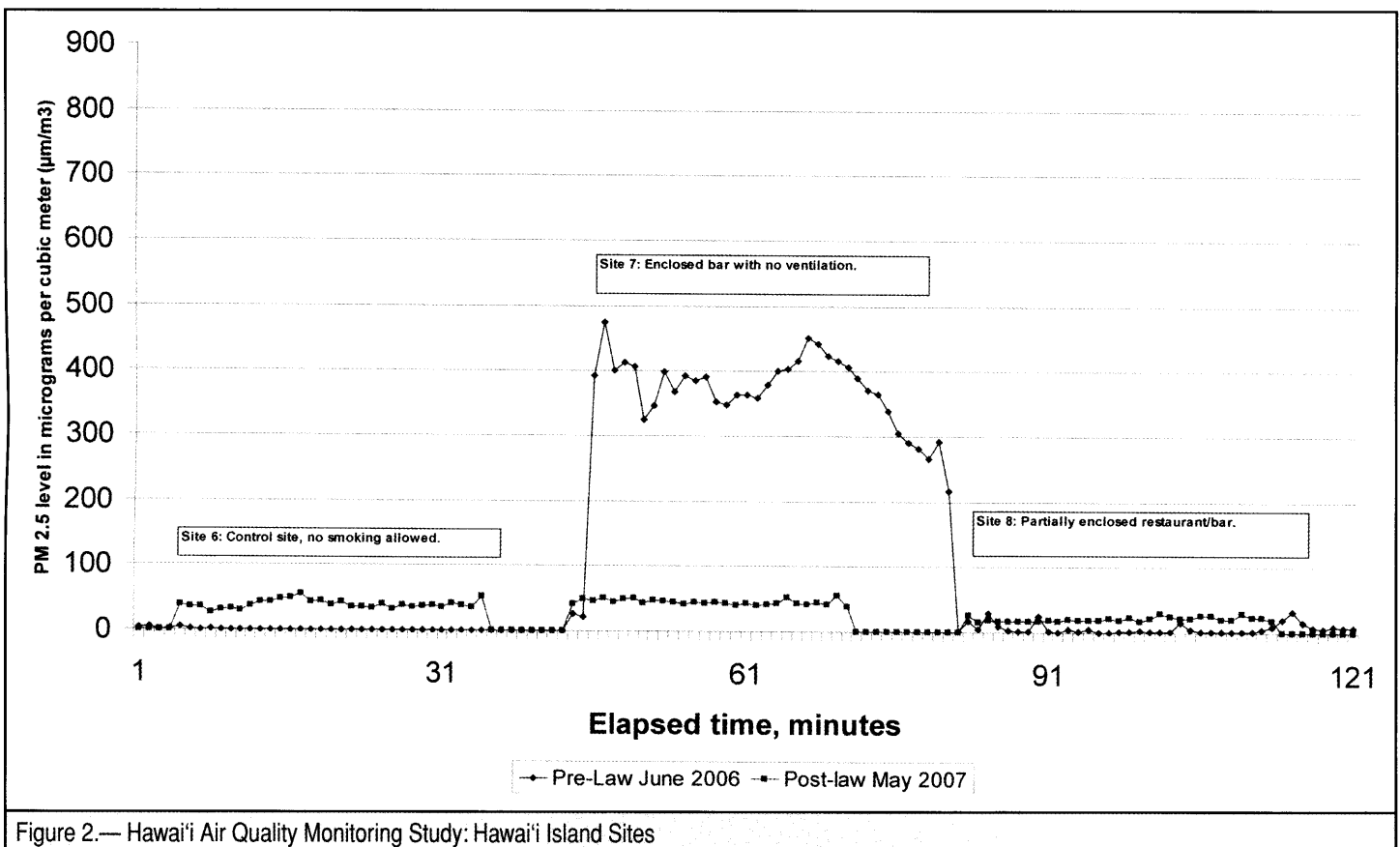


Figure 2.— Hawai'i Air Quality Monitoring Study: Hawai'i Island Sites

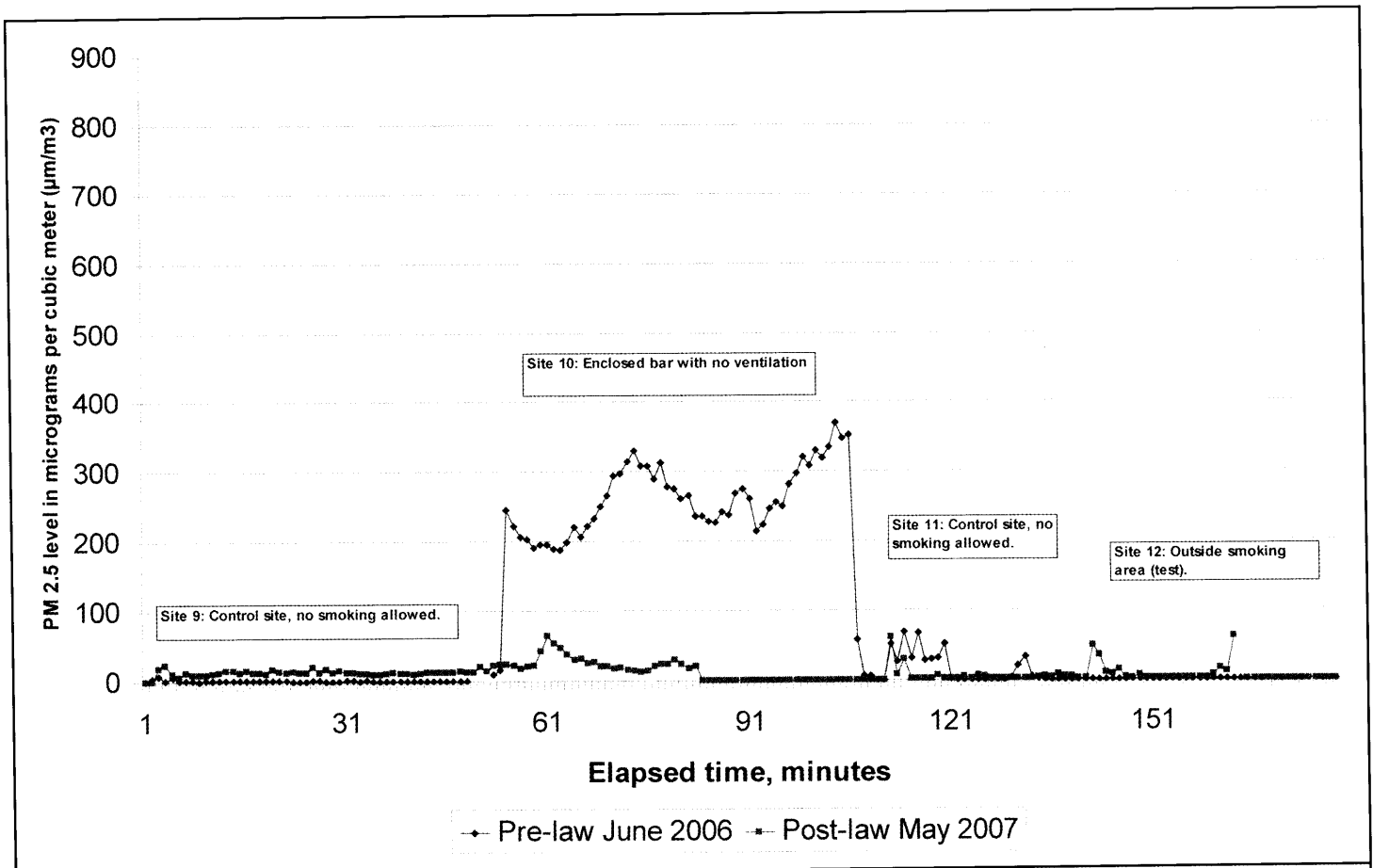


Figure 3.— Hawai'i Air Quality Monitoring Study: Maui Sites

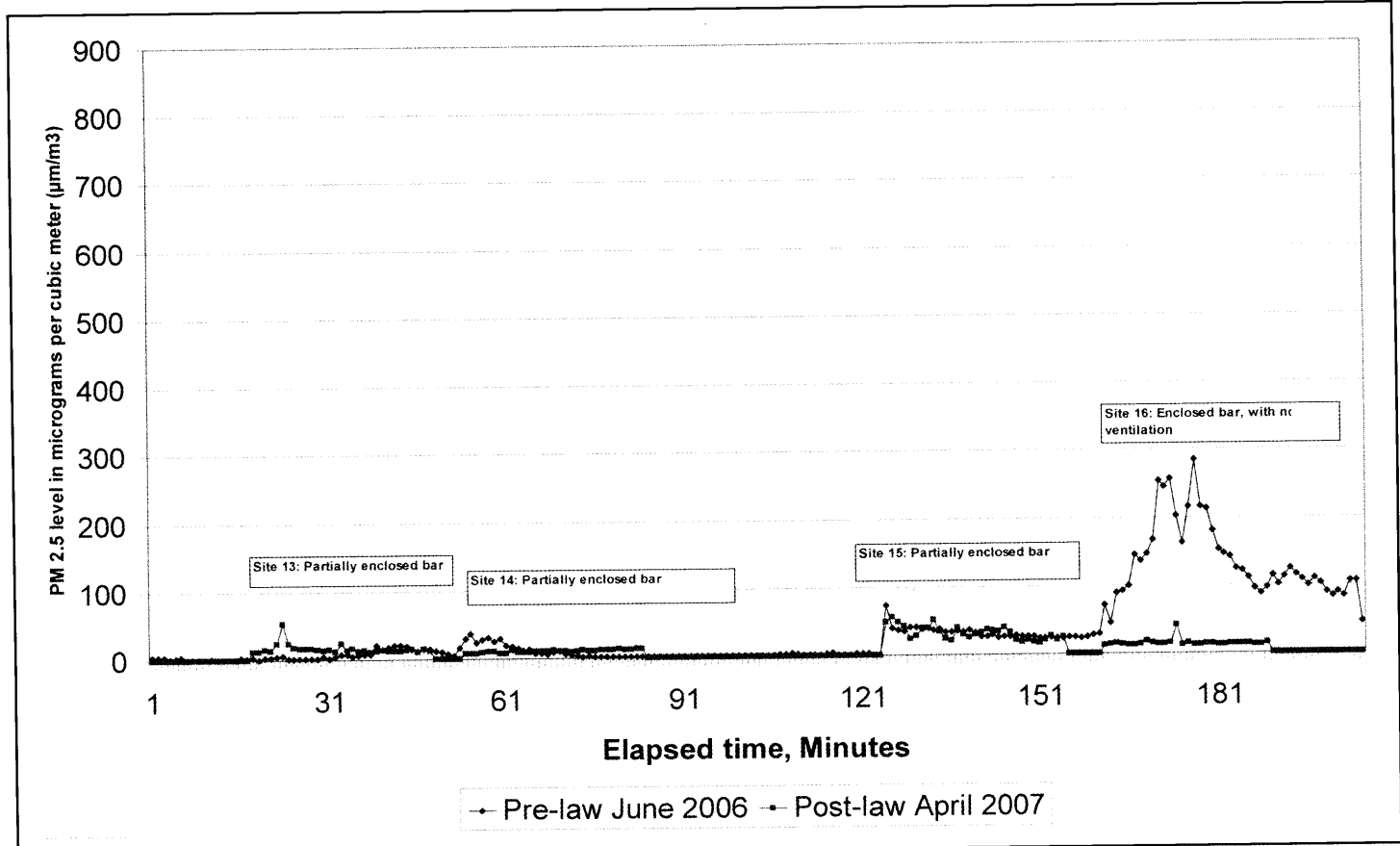


Figure 4.— Hawai'i Air Quality Monitoring Study: Kaua'i Sites

Site	Type of venue	# of people at venue		Average temperature during date/time of measurement ¹		Average humidity during date/time of measurement		Wind speed (mph) during date/time of measurement		Daily average outdoor air quality PM 10 (µm/m ³) during monitoring	
		Before 11/06	After 11/06	Before 11/06	After 11/06	Before 11/06	After 11/06	Before 11/06	After 11/06	Before 11/06	After 11/06 ²
Site 1 (O'ahu-Honolulu)	Enclosed bar	15-20	11-15	78.1 F	75.0 F	62%	58%	ENE 12.7	E 16.1	9	19
Site 2 (O'ahu-Honolulu)	Partially enclosed restaurant/bar	80-120	100-110	77.0 F	75.0 F	66%	62%	ENE 11.5	E 16.1	9	19
Site 3 (O'ahu-Honolulu)	Enclosed bar	30	18-24	78.1 F	73.9 F	64%	66%	ENE 9.2	Var. 6.9	14	21
Site 4 (O'ahu-Honolulu)	Enclosed bar	200	150-200	75.0 F	73.9 F	69%	66%	NNE 6.9	ENE 9.2	14	21
Site 5 (O'ahu-Honolulu)	Enclosed bar	250-270	100-125	75.0 F	73.9 F	69%	64%	NE 8.1	E 4.6	14	19
Site 6 (Big Island-Kona)	Control site	28-36	25-32	79.0 F	77.0 F	64%	69%	Var 4.6	SSW 8.1	3	20
Site 7 (Big Island-Kona)	Enclosed bar	25-50	20-22	77.0 F	77.6 F	54%	61%	NE 9.2	WSW 5.8	3	20
Site 8 (Big Island-Kona)	Partially enclosed restaurant/ bar	40-45	23-28	82.0 F	82.0 F	58%	51%	SSW 6.9	S 15.0	3	20
Site 9 (Maui-Kahului)	Control site	7-20	4-18	79.0 F	82.0 F	64%	45%	ENE 21.9	NE 10.4	20	27
Site 10 (Maui-Wailuku)	Enclosed bar	40-50	66-69	76.5 F	78.1 F	73%	52%	NNE 12.7	ENE 13.8	20	27
Site 11 (Maui-Pa'ia)	Control site	18-27	37-49	78.1 F	81.0 F	68%	54%	NNE 12.7	NNE 5.8	14	22
Site 12 (Maui-Pukalani)	Outside smoking area	4-8	3-4	80.1 F	75.9 F	62%	69%	NNW 6.9	NNE 16.1	19	70
Site 13 (Kaua'i-Hanalei)	Partially enclosed restaurant/bar	17-24	24-32	77.5 F	73.9 F	70%	71%	ENE 19.6	NE 13.8	18	—
Site 14 (Kaua'i-Kilauea)	Partially enclosed restaurant/bar	27-38	12-22	77.0 F	73.0 F	71%	81%	ENE 19.0	NNE 15.0	18	—
Site 15 (Kaua'i-Lihue)	Control site	8-12	51-60	77.6 F	73.9 F	73%	68%	NE 16.2	NNE 16.1	14	—
Site 16 (Kaua'i-Lihue)	Enclosed bar	19-23	9-13	77.0 F	73.9 F	71%	68%	NE 18.4	NNE 17.3	14	—

¹Based on zip code of venue for each island: <http://www.wunderground.com>.

²Data for Kaua'i post-law were not available.

overall average at 16.3% (below the state smoking prevalence level). Partially enclosed bars and restaurants had much lower cigarette density and smoker prevalence than the enclosed venues monitored in this assessment. After implementation of the law, the average number of patrons at enclosed venues decreased at all sites. At partially enclosed sites, the average number of patrons decreased at 2 sites, and remained about the same at one and increased at another.

Discussion

Hawai'i is a diverse state in both its geography and demographics. Of the more than 1.2 million residents, there is no single majority ethnic group. The 2000 US Census estimated a resident population of 1,211,537 and a projected population of 1,285,498 in 2006.¹⁷ The state's population is unevenly distributed among the islands, with the majority (72.3%) of the residents on O'ahu, 12.3% on Hawai'i, 4.8% on Kaua'i, and 10.6% in the tri-island county of Maui (Maui, Moloka'i, and Lana'i).

Data from the 2006 Behavioral Risk Factor Surveillance Survey¹⁸ show that the overall reported smoking rate for the state stands at 17.5% (95% CI 16.3%-18.9%). Reported smoking among men was 19.2% (95% CI 17.1%-21.4%) and among women was 15.9% (95% CI 14.3%-17.6%) in 2006. Native Hawaiians continue to have the highest smoking rates in the state at 27.4% (95% CI 23.1%-32.2%). Health disparities continue, with increases from previous years among the unmarried, the unemployed, those with less education, and those with low income. Although 2006 rates are slightly higher on the Big Island (19.2% with 95% CI 16.7%-22.0%) and Maui (18.7% with 95% CI 16.0%-21.8%), than on Kaua'i (17.7% with 95% CI 14.4%-21.5%) and O'ahu (17.1% with 95% CI 15.4%-18.9%), all county rates show convergence in recent years.

Examining the data from the 15 relevant sites studied for this air quality monitoring assessment, the findings indicate that prior to the Smoke-Free Workplace and Public Places Law being implemented, air quality at 7 sites that were enclosed bars/restaurants where people were smoking all had high levels of PM_{2.5} exceeding the EPA average daily limit of 65 µg/m³. Four sites that were partially enclosed bars/restaurants where people were smoking all had air quality PM_{2.5} levels below the EPA 24 hour average daily limit. The 4 control sites (where smoking was not permitted or observed), did not show any discernable levels of particulate matter (i.e. had levels below the EPA average limit). After implementation of the law, air quality was again monitored at 14 of the relevant sites and 1 alternate site and findings indicate that all venues had air quality PM_{2.5} levels below the EPA average daily limit. One partially enclosed bar next to a major intersection had fluctuating high and low particulate matter readings both before and after implementation of the new law, but with an average level below the EPA 24 (daily) average limit of 65µg/m³ (this site has since closed).

The results must take into consideration some degree of variation due to testing variables including differential equipment calibration (pre and post). Readings of levels of particulate matter at all sites after the implementation of the law show a slight (but consistent) increase in particulate matter readings, although still below the EPA average daily limit. This is likely the result of variables in the calibration of the two different instruments at the two different times, factors in either indoor or outdoor air quality at venues (e.g. cooking, VOG), or both. These observed post-law increases cannot be due to smoking. The discrepancy with regard to the apparent increase in PM_{2.5} at some sites should not be taken to indicate that air quality actually worsened, but should be attributed to differential equipment calibration.

Hawai'i Sites	Type of venue	Size (m3)	Cigarette density*		Average PM _{2.5} level in micrograms per cubic meter (µg/m ³)		% reduction or increase in average PM _{2.5}
			Before 11/06 (measured in June & July 2006)	After 11/06 (measured in April & May 2007)	Before 11/06 (measured in June & July 2006)	After 11/06 (measured in April & May 2007)	
Site 1 (O'ahu)	Enclosed bar/restaurant	1,270	0.18	0	64.0	6.7	-89.5
Site 3 (O'ahu)	Enclosed bar/restaurant	343	2.19	0	232.8	20.5	-91.2
Site 4 (O'ahu)	Enclosed bar	581	8.61	0	84.5	12.5	-85.2
Site 5 (O'ahu)	Enclosed bar	1,359	5.02	0	319.6	16.7	-94.8
Site 7 (Big Island)	Enclosed bar	2,537	0.32	0	360.9	45.5	-87.4
Site 10 (Maui)	Enclosed bar	2,243	0.11	0	240.8	26.2	-89.1
Site 16 (Kaua'i)	Enclosed bar	686	0.34	0	137.4	14.0	-89.8
Mean		1,288	2.4	0	205.7	20.3	-90.1
Site 2 (O'ahu)	Partially enclosed bar/restaurant	1,338	1.05	0	31.6	42.0	+32.9
Site 8 (Big Island)	Partially enclosed bar/restaurant	1,831	0.07	0	6.32	20.7	+69.5
Site 13 (Kaua'i)	Partially enclosed bar/restaurant	1,223	.16	0	8.3	15.7	+47.1
Site 14 (Kaua'i)	Partially enclosed bar/restaurant	3,200	0.07	0	5.8	10.1	+42.6
Mean		1,898	.34	—	13.0	22.0	+40.1
Site 6 (Big Island)	Control site, partially enclosed, no smoking allowed	—	0	0	.04	38.5	+99.9
Site 9 (Maui)	Control site, enclosed, no smoking allowed	—	0	0	.81	12.9	+93.7
Site 11 (Maui)	Treated as a control site (Partially enclosed bar/restaurant, smoking not observed)	—	0	0	.18	37.3	+99.5
Site 15 (Kaua'i)	Treated as a control site (Partially enclosed bar/restaurant, smoking not observed)	—	0	0	30.4	30.9	+1.2
Mean		—	—	—	7.9	29.9	+73.6

* Average number of burning cigarettes per 100 m3.

tion at pre and post-tests or other non-smoking variables post-law (e.g. cooking, candles). Any other conclusions based upon the above mentioned discrepancy would be unwarranted. Further studies are recommended to measure post-ban air quality.

Unlike other studies examining indoor air quality before and after implementation of smoking bans, this assessment used volunteers to conduct the air quality monitoring. However, the protocols for the actual monitoring with the SidePak machine were followed based on the instructions from the manufacturer, so this likely did not affect the data on actual air quality. Volunteers were not responsible for taking measurements of the different venues during testing (square footage and ceiling height); this information was obtained later through information provided by the County Liquor Commissions, by actual measurement and phone inquiries. Some of these measurements are rounded estimates, but are very likely accurate. Thus, one possible limitation regarding the sampling frame (selection of sites) may be inherent due to convenience sampling (selection bias) by volunteers. For the enclosed bars during pre-law monitoring, 3 of the 7 sites were well known gay-friendly bars, representing 3 of the 5 gay-friendly bars in the state (all on the island of O'ahu). Moreover, at two of these sites, Sites 4 and 5 on the date in

question, both bars were very crowded. This, the volunteer pointed out, was due to the annual Gay/Lesbian pageant event earlier in the evening, and there was free entry to Site 5 with a pageant stub, so presumably, as noted by the volunteer, people went to the bar after the pageant. Further, Site 4, which is next to Site 5, closes at 2:00 AM, while Site 5 is open until 4:00 AM. So, the readings from these sites may have been unusually high because of these unique circumstances (e.g. smoking prevalence is higher among gays and lesbians).^{19,20} Data from the Hawai'i 2006 Adult Tobacco Survey provide additional evidence on this with those who reported being non-heterosexual adults (homosexual, bisexual, or something else) were significantly more likely to smoke cigarettes (34.1%) than their heterosexual counterparts (13.1%).²¹ The point is only to illustrate probable sources of sampling bias in the resultant total sample of venues where testing was conducted. Since the volunteers were members or leaders from the various county tobacco coalitions, this may have also have affected the nature of the data collection, particularly on the (less populated) neighbor islands (pre-law).²²

Despite these limitations, the findings indicate that there is evidence that there was a definitive proportionate reduction in particulate matter at enclosed venues after implementation of the new law.

Table 3.— Cigarette Density, Smoker Prevalence and Number of Patrons, before and After Law

Hawai'i Sites	Type of venue	Cigarette density*		Smoker prevalence (# smoking, of total # of patrons)		Average total number of patrons		% reduction or increase in average numbers of patrons
		Before 11/06 (measured in June & July 2006)	After 11/06 (measured in April & May 2007)	Before 11/06 (measured in June & July 2006)	After 11/06 (measured in April & May 2007)	Before 11/06 (measured in June & July 2006)	After 11/06 (measured in April & May 2007)	
Site 1 (O'ahu)	Enclosed bar/restaurant	0.18	0	13.3	0	17.3	13	-24%
Site 3 (O'ahu)	Enclosed bar/restaurant	2.19	0	19.3	0	38.8	22.7	-41%
Site 4 (O'ahu)	Enclosed bar	8.61	0	25.0	0	200	174.3	-13%
Site 5 (O'ahu)	Enclosed bar	5.02	0	26.6	0	256.7	116.7	-55%
Site 7 (Big Island)	Enclosed bar	0.32	0	23.5	0	34	20.7	-38%
Site 10 (Maui)	Enclosed bar	0.11	0	5.3	0	47.3	6.7	-85%
Site 16 (Kauai)	Enclosed bar	0.34	0	1.3	0	20.3	10.7	-45%
Mean		2.4	—	16.3	—	87.8	60.7	—
Site 2 (O'ahu)	Partially enclosed bar/restaurant	1.05	0	13.1	0	107	105	-2%
Site 8 (Big Island)	Partially enclosed bar/restaurant	0.07	0	3.0	0	43.3	26.3	-40%
Site 13 (Kauai)	Partially enclosed bar/restaurant	.16	0	8.8	0	22.7	27	+15%
Site 14 (Kauai)	Partially enclosed restaurant/bar	0.07	0	3.1	0	32.7	17.3	-48%
Mean		.26	—	7	—	51.4	43.9	—

* Average number of burning cigarettes per 100 m3.

This reduction was dramatic and illustrates that the Smoke-Free Work and Public Places law does protect people from secondhand smoke in enclosed bars and restaurants. However, there was no evidence that partially enclosed restaurants/bars had any dangerous level of particulate matter either before or after the law; all had air quality PM_{2.5} levels at 30 or much lower, below the EPA average daily limit. Much more research is needed in the area of partially enclosed venues, particularly in light of the recent push for banning smoking in outdoor areas given the controversy over the purported and actual effects of secondhand smoke.²³⁻²⁵

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