A 20-Country Comparison of Levels of Indoor Air Pollution in Different Workplaces

Conducted By:

Roswell Park Cancer Institute, Department of Health Behavior

Andrew Hyland, PhD
Mark J. Travers, MS
Cheryl Higbee, MPH
K. Michael Cummings, PhD, MPH

International Agency for Research on Cancer

Carolyn Dresler, MD, MPA

Division of Public Health Practice, Harvard School of Public Health

Carrie Carpenter, PhD, MS
Gregory Connolly, DMD, MPH

July 2006

The research was funded by grants from the Flight Attendant Medical Research Institute (FAMRI), and from the U.S. National Cancer Institute/NIH (from the Roswell Park Transdisciplinary Tobacco Use Research Center (TTURC), P50 CA111236.

Abstract

The Framework Convention for Tobacco Control (FCTC) calls for countries to adopt measures providing protection from exposure to tobacco smoke. The first comprehensive nationwide policies took effect in 2004, although the vast majority of nations lack comprehensive policies. The aim of this study was to conduct indoor air quality measurements in at least 20 countries with different regulations to provide a comparison of secondhand smoke levels.

The TSI Sidepak was used to measure the level of particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) in pubs, restaurants, retail outlets, airports, and other workplaces in at least 20 geographically dispersed countries between November 2005 and April 2006. $PM_{2.5}$ are harmful fine particles that are easily inhaled deep into the lungs and are emitted in large quantities from burning cigarettes. Collaborators in each country were trained through a joint effort between IARC, Roswell Park Cancer Institute, and the Harvard School of Public Health. The study goal was to test air quality in 1,000 establishments worldwide.

The $PM_{2.5}$ level in establishments where smoking is permitted are 9 times greater than the level in places where smoking is prohibited and on average these levels were far greater what the US Environmental Protection Agency has concluded is harmful to human health.

Levels of indoor air pollution in places that allow smoking are typically at hazardous levels. Comprehensive smoke-free regulations are the most effective strategy to reduce secondhand smoke exposure. These findings underscore the importance of compliance with the FCTC provision for protection from exposure to tobacco smoke.

Introduction

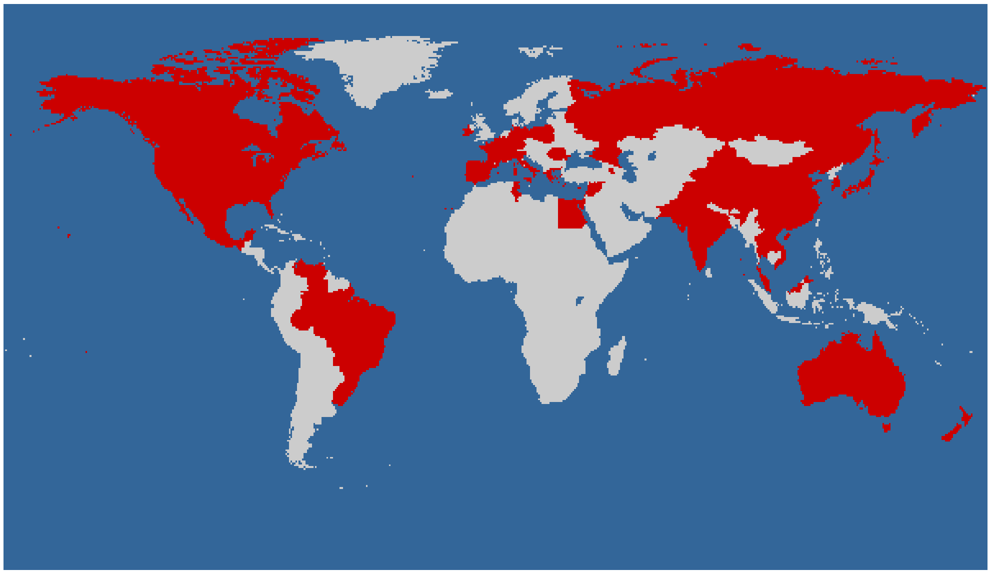
Secondhand smoke is a mixture of the smoke given off by the burning end of a cigarette, pipe, or cigar, and the smoke exhaled from the lungs of smokers. There are more than 4,800 chemicals in secondhand smoke including 69 carcinogens as well as other chemicals that are irritants, toxicants and mutagens.[1] In 1986, a report of the U.S. Surgeon General concluded that secondhand smoke is a cause of disease in healthy nonsmokers.[2] Subsequent studies from the U.S. Environmental Protection Agency,[3] the U.S. National Toxicology Program,[4] and the International Agency for Research on Cancer[5] have classified secondhand smoke as a known human carcinogen.

<u>Smoke-free Legislation around the World</u>

In May 2003, the member countries of the World Health Organization adopted an historic tobacco control treaty, the Framework Convention on Tobacco Control (FCTC). Article 8 of the Framework Convention on Tobacco Control (FCTC) calls for the expansion of smoke-free places at the national and other jurisdictional levels in signatory countries.

Specifically, signatory nations "recognize that scientific evidence has unequivocally established that exposure to tobacco smoke causes death, disease and disability." And that "Each Party shall adopt and implement in areas of existing national jurisdiction as determined by national law and actively promote at other jurisdictional levels the adoption and implementation of effective legislative, executive, administrative and/or other measures, providing for protection from exposure to tobacco smoke in indoor workplaces, public transport, indoor public places and, as appropriate, other public places." A total of 128 countries have ratified the World Health Organization's Framework Convention on Tobacco Control, which became international law in February, 2005.[6]

Partly driven by Article 8 of the FCTC calling for greater secondhand smoke protection policies, several countries have initiatives to implement smoke-free regulations at the national or sub-national level. For example, in 2004, Ireland, Norway, and New Zealand became the first countries to enact comprehensive smoke-free indoor air laws. In 2006, Uruguay became the first South American country to implement a 100% smoke-free regulation in workplaces, restaurants, and bars. Other countries throughout Europe, Asia, North and South America, and the Pacific have taken action to reduce exposure to secondhand smoke in workplaces and public places.[7] While this is encouraging, smoking in indoor public places is still the norm in the vast majority of nations worldwide as they work toward achieving the FCTC standard.



The participating countries in the Global Air Monitoring Study

The goal of this study was to provide the latest scientific equipment and methods to practitioners around the world in at least 20 different countries and develop a global scorecard of secondhand smoke exposure. In each country, efforts were made to test air quality in each of the following: restaurants, bars, transportation outlets (airports, train stations), and other (hotels, shopping malls, offices and outdoor ambient air venues). It was hypothesized that indoor air would be less polluted in those venues where smoking is prohibited and where smoking does not occur, than in those places where smoking is present.

To date, air quality has been tested in 22 countries: Armenia, Belgium, Canada, France, Germany, Greece, Laos, Lebanon, Malaysia, New Zealand, Pakistan, Poland, Portugal, Romania, Spain, Syria, Thailand, Tunisia, United Kingdom, United States, Uruguay, and Vietnam. An additional 17 countries are planning on participating, for a total of 39 potential countries included in the study.

Methods

Overview

Air quality was assessed in 1,132 places in 22 countries. Data collection in Canada took place in 2004, data collection in the United States took place between 2003 through 2006 and data in the remaining countries wer collected in 2005 and 2006. The places tested included restaurants, bars, transportation areas, including airports and train stations, and other types of venues, including hotels, shopping malls, offices and outdoor ambient air venues. Testing sites were conveniently selected by tobacco control professionals in their respective countries. Testing was completed in smoking and smoke-free places on all the days of the week and at all times of the day.

Training of Data Collection Staff

In order to train data collection staff in each participating country, a web-based training module was created including detailed, step-by-step instructions on the operation of the air monitoring equipment. This training module utilizes a large number of pictures so collaborators can see the equipment and its operation, as would normally be done in-person. The website also includes a message board where collaborators can post questions and comments, a “FAQ” or frequently asked questions section and brief biographies of the researchers collaborating on the study. With the combination of the web-based training module, print materials, and a training video, the collaborators received adequate training in collecting indoor air quality data for this study.

Selection of Countries and Coordination of Data Collection

Countries included in the study were identified first through existing contacts in individual countries, and then with the help of the International Agency for Research on Cancer (IARC). IARC is a renowned international health agency and as such has been invaluable in providing help identifying global collaborators, translating our training materials into different languages when necessary, and disseminating the results globally. Specific tailored venue sampling frames were developed for each country taking into account conditions in those countries while striving to maintain comparability across countries.

Measurement Protocol

A standard measurement protocol was used by data collectors across study sites. Establishments were tested for a minimum of 30 minutes. The number of people inside the venue and the number of burning cigarettes were recorded every 15 minutes during sampling. These observations were averaged over the time inside the venue to determine the average number of people on the premises and the average number of burning cigarettes. For most establishments, a sonic measure (Zircon Corporation, Campbell, CA) was used to measure room dimensions and hence the volume of each of the venues. When using the sonic measure to calculate room dimensions was not possible, room measurements were made through estimation.

TSI SidePak AM510 Personal Aerosol Monitor

In each establishment, respirable suspended particles (RSPs) were measured using a TSI SidePak AM510 Personal Aerosol Monitor (TSI, Inc., St. Paul, MN, USA). This portable light-scattering aerosol monitor was fitted with a 2.5 µm impactor in order to measure the concentration of particulate matter with a mass median aerodynamic diameter less than or equal to 2.5 µm, or $PM_{2.5}$. The Sidepak was used with a calibration factor setting of 0.32, suitable for secondhand smoke. The SidePak uses a built-in sampling pump to draw air through the device where the particulate matter in the air scatters the light from a laser. The mass concentration of particles is determined by the amount of light scattering.

> ***$PM_{2.5}$ is the concentration of particulate matter in the air smaller than 2.5 microns in diameter. Particles of this size are released in significant amounts from burning cigarettes, are easily inhaled deep into the lungs, and are associated with pulmonary and cardiovascular disease and mortality.***

Secondhand smoke is not the only source of indoor particulate matter, but $PM_{2.5}$ monitoring is highly sensitive to it. While ambient particle concentrations and cooking are additional sources of indoor particle levels, smoking is generally the largest contributor to indoor air pollution.[8]

The equipment was set to a one-minute log interval, which averages the previous 60 one-second measurements. The SidePak was zero-calibrated prior to each use by attaching a HEPA filter according to the manufacturer's specifications. Sampling was discreet in order not to disturb the occupants' normal behavior. The monitor was generally located in a central location on a table or bar and not on the floor so the air being sampled was within the occupants' normal breathing zone. For each venue, the first and last minute of logged data were removed because they are averaged with outdoors and entryway air. The remaining data points were averaged to provide an average $PM_{2.5}$ concentration within the venue. Associates in each country did the sampling, and Roswell Park Cancer Institute staff analyzed the data.

In order to protect the public health, the U.S. Environmental Protection Agency has set 15 $\mu g/m^3$ as the average annual exposure limit of $PM_{2.5}$ and 65 $\mu g/m^3$ as the 24-hour exposure limit.[9]

Statistical Analyses

The primary goal was to assess the difference in the average levels of $PM_{2.5}$ in places that were smoke-free (no smoking observed during sampling) and places that were not (smoking was observed during sampling). Additionally, levels in venues where smoking occurred were compared with levels in venues in Ireland where there is a comprehensive smoking policy. The data from Ireland come from another study and serve as a reference group for the data in this study.[10] Finally, the comparison between smoking and smoke-free venues is replicated for each type of venue. Statistical significance is assessed using the Mann-Whitney U-test. Descriptive statistics include the type of venue (smoke-free or smoking), the mean $PM_{2.5}$, the country, and the city or region, if this information was provided.

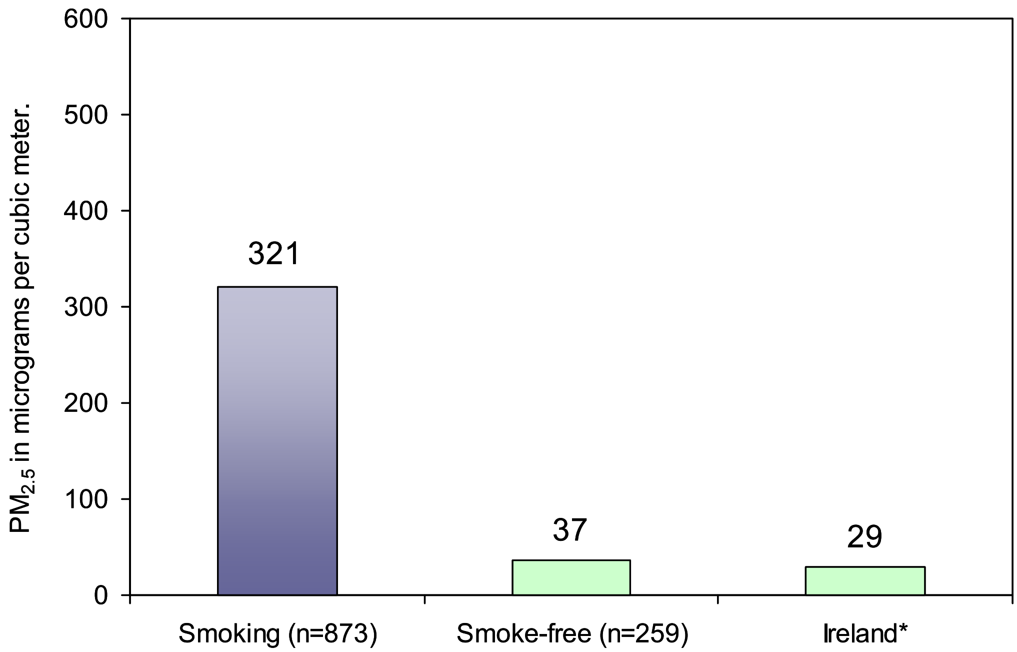
Results

Table 1 provides a summary of the data collected in 1,132 places in 22 countries.

Table 1. Summary of Smoke-free Versus Smoking Places by Country			
Country	Type	N	Mean $PM_{2.5}$ (ug/m^3)
1) Armenia		16	197
	Smoke-Free	2	31
	Smoking	14	233
2) Belgium		68	393
	Smoke-Free	6	43
	Smoking	62	427
3) Canada		20	66
	Smoke-Free	13	10
	Smoking	7	171
4) France		59	380
	Smoke-Free	14	37
	Smoking	45	487
5) Germany		100	318
	Smoke-Free	3	19
	Smoking	97	327
6) Greece		51	276
	Smoke-Free	2	52
	Smoking	49	285
* Ireland	Smoke-Free	25	29
7) Laos	Smoking	51	168
8) Lebanon	Smoking	9	420
9) Malaysia		50	154
	Smoke-Free	10	46
	Smoking	40	181
10) New Zealand		47	14
	Smoke-Free	44	14
	Smoking	3	17
11) Pakistan	Smoking	27	169
12) Poland		74	262
	Smoke-Free	40	79
	Smoking	34	477
13) Portugal		29	212
	Smoke-Free	6	63
	Smoking	23	251
14) Romania		40	459
	Smoke-Free	1	47
	Smoking	39	469
15) Spain		13	215
	Smoke-Free	6	33
	Smoking	7	371
16) Syria	Smoking	40	464
17) Thailand		53	171
	Smoke-Free	27	29
	Smoking	26	319
18) Tunisia		33	275
	Smoke-Free	13	64
	Smoking	20	412
19) United Kingdom	Smoking	64	285
20) United States		227	197
	Smoke-Free	64	22
	Smoking	163	265
21) Uruguay		11	210
	Smoke-Free	4	27
	Smoking	7	314
22) Vietnam		49	328
	Smoke-Free	4	83
	Smoking	45	350
*Note: Data from Ireland come from another study and serve as a reference group to the data in this study (Mulcahy et.al., 2006)			

As shown in Figure 1, 259 places were smoke-free, and the average $PM_{2.5}$ level in these places was 37 micrograms per cubic meter (μg/ m^3), ranging from 1 to 347 μg/ m^3. The average $PM_{2.5}$ level in the 873 places where smoking was observed was 321 μg/ m^3 , ranging from 4 to 3,764 μg/ m^3.

Figure 1. Average Fine Particle Air Pollution – All Countries



*Data from Ireland come from another study and serve as a reference group to the data in this study (Mulcahy et.al., 2006)

The level of indoor air pollution was 88% lower in the places that were smoke-free compared to those where smoking was observed. The difference between the mean $PM_{2.5}$ levels was statistically significant ($p<.001$), as determined by the Mann-Whitney U-test.

Figure 2 shows the average air pollution levels found in restaurants, bars, transportation places, and other types of places. Across each type of place, the lowest level of indoor air pollution was found in smoke-free places.

Figure 3 shows the average air pollution levels found across world regions: Africa (Tunisia), the Americas (Canada, United States, Uruguay), Europe (Belgium, France, Germany, Greece, Poland, Portugal, Romania, United Kingdom), North Asia and the Middle East (Armenia, Lebanon, Pakistan, Syria), and Southeast Asia (Laos, Malaysia, New Zealand, Thailand, Vietnam).

Figure 2. Average Fine Particle Air Pollution by Type of Place

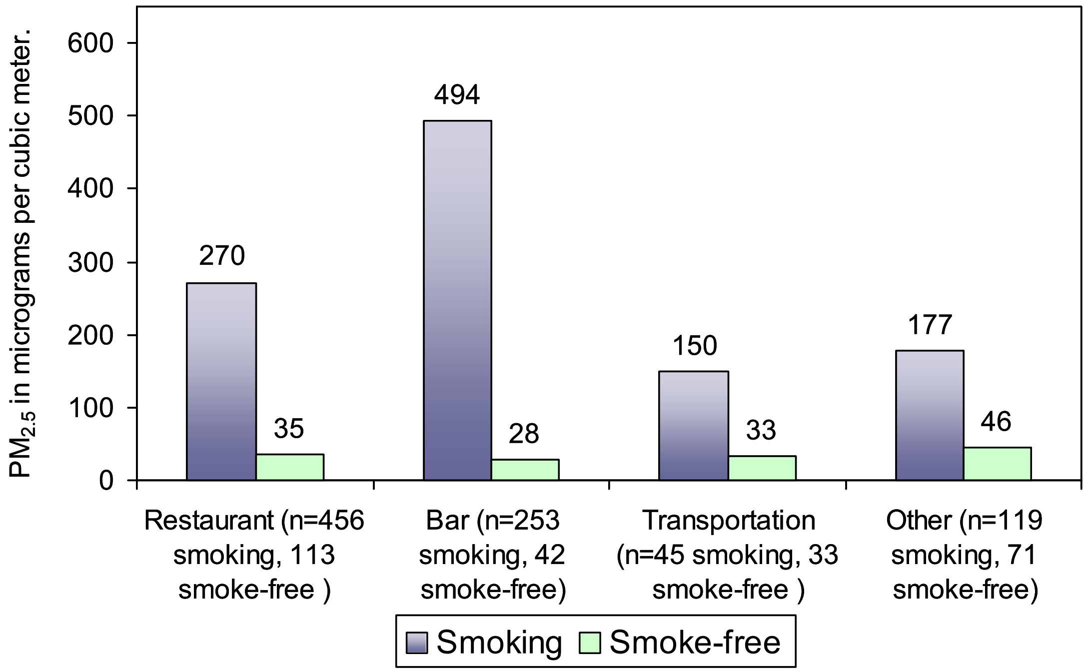


Figure 3. Average Fine Particle Air Pollution by World Region

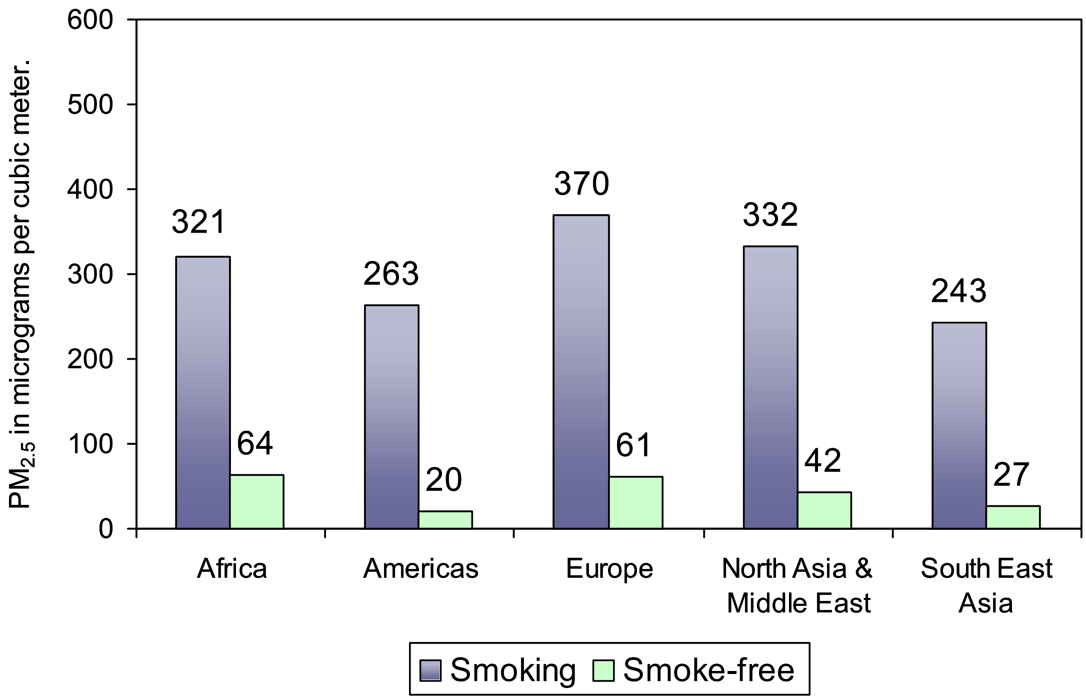
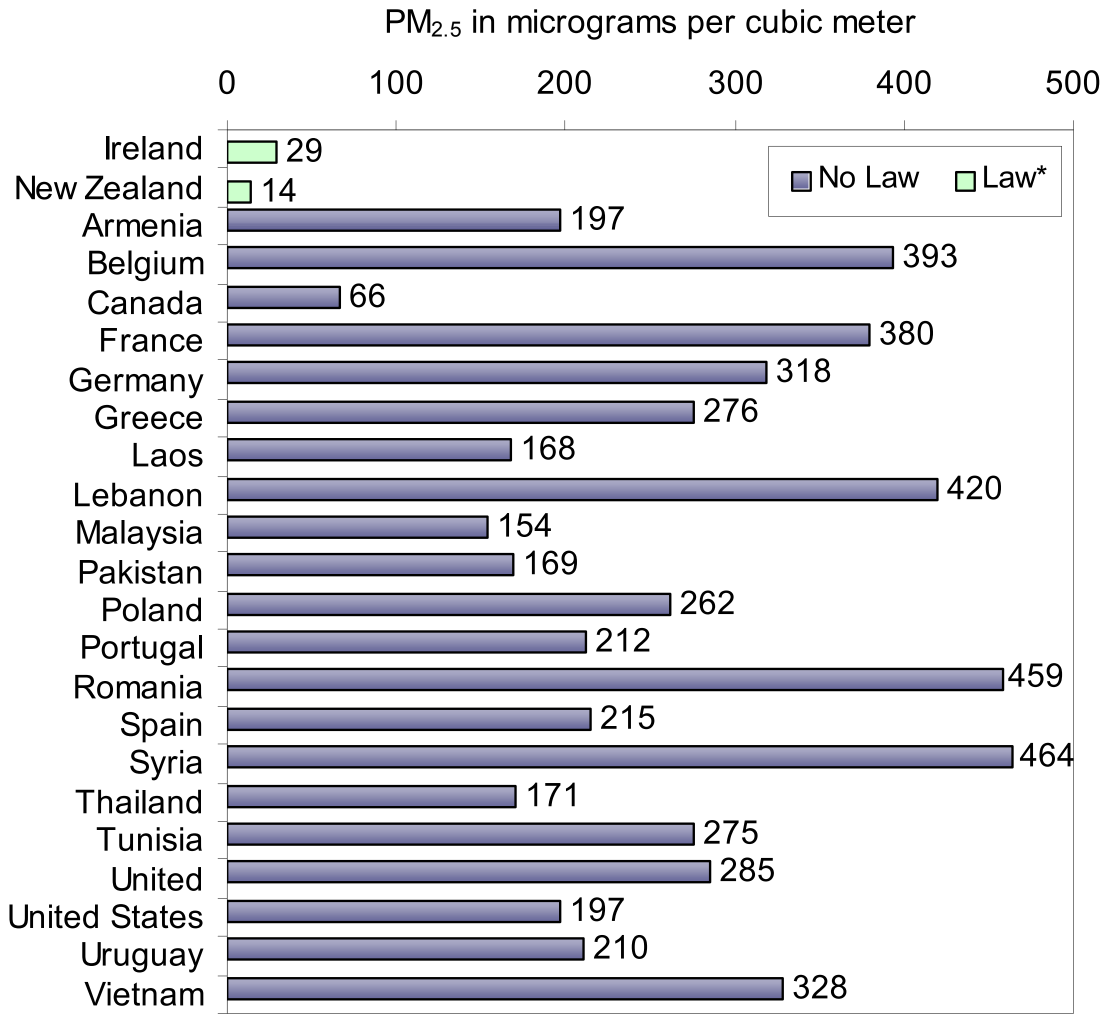


Figure 4 shows the average indoor air pollution level in each of the 22 countries. Average $PM_{2.5}$ levels in Ireland and New Zealand, where there are comprehensive clean indoor air policies at the national level, were lowest. High levels of indoor air pollution exist in countries that do not have comprehensive clean indoor air policies.

Figure 4. Average Fine Particle Air Pollution by Country



* Ireland and New Zealand have national level, comprehensive clean indoor air policies. The other countries do not.

Discussion

In the United States, the EPA cited over 80 epidemiologic studies in creating a particulate air pollution standard in 1997. In order to protect the public health, the EPA has set a limit of 15 μg/m^3 as the average annual level of $PM_{2.5}$ exposure.[9] Based on the latest scientific evidence, the EPA staff currently proposes even lower $PM_{2.5}$ standards to adequately protect the public health,[11] making the high $PM_{2.5}$ exposures of people in smoking environments even more alarming.

Previous studies have evaluated air quality by measuring the change in levels of respirable suspended particles (RSP) between smoke-free venues and those that permit smoking. Ott et al. did a study of a single tavern in California and showed an 82% average decrease in RSP levels after smoking was prohibited by a city ordinance. Repace studied 8 hospitality venues in Delaware before and after a statewide prohibition of smoking in these types of venues and found that about 90% of the fine particle pollution could be attributed to tobacco smoke.[12] Similarly, in a study of 22 hospitality venues in Western New York, Travers et al. found a 90% reduction in RSP levels in bars and restaurants, and 84% reduction in large recreation venues such as bingo halls and bowling alleys, and even a 58% reduction in locations where only SHS from an adjacent room was observed at baseline.[13] A cross-sectional study of 53 hospitality venues in 7 major cities across the U.S. showed 82% less indoor air pollution in the locations subject to smoke-free air laws, even though compliance with the laws was less than 100%.[14]

Other studies have directly assessed the role SHS exposure has on human health. One study found that respiratory health improved rapidly in a sample of bartenders after a state smoke-free workplace law was implemented in California,[15] and another study reported a 40% reduction in acute myocardial infarctions in patients admitted to a regional hospital during the 6 months that a local smoke-free ordinance was in effect.[16] Farrelly et al. also showed a significant decrease in both salivary cotinine concentrations and sensory symptoms in hospitality workers after New York State's smoke-free law prohibited smoking in their worksites.[17]

A limitation to be considered when interpreting these data is that secondhand smoke is not the only source of indoor particulate matter. Ambient particle concentrations and cooking are additional sources of indoor particle levels, although smoking is generally the largest contributor to indoor air pollution. In some countries, the level of pollution in smoke-free places was higher than in other countries. There are a few possible explanations for this discrepancy. The higher levels of indoor air pollution seen in some smoke-free places could be due to other factors, such as cooking and open fireplaces. Another explanation is that there was smoking occurring in these venues, but not at the time when the data was collected. However, average levels of indoor air pollution in smoke-free places in general were found to be lower than in smoking places.

Conclusions

Restaurants, bars, transportation outlets, and other types of places that are "smoke-free" are significantly less polluted than places where smoking occurs, and this is true around the globe. Comprehensive smoke-free regulations are the most effective strategy to reduce secondhand smoke exposure. These findings underscore the importance of compliance with the FCTC provision for greater smoke-free worker protection policies.

Acknowledgements

Contributors to the Global Air Monitoring Study:

ARMENIA

Varduhi Petrosyan, MS, PhD
Narine Movsisyan, MD, MPH
Marietta Khurshudyan, MPH
Arayik Sargsyan, MD, MPH

BELGIUM

Isabelle Convié

CANADA

Geoffrey T. Fong, PhD
David Hammond, PhD
Taryn Sendzik, BA
Matthew Sendzik, BASc
Lindsay Bridgman, BA
Bryanne Gilkinson
Allison Saunders, BSc
Tara Elton-Marshall, MASc
Zachary Marshall

FRANCE

Sylviane Ratte, MA
Christelle Nieraad, MA
Nicolas Villain, MA

GERMANY

Dr. Martina Pötschke-Langer
Bjorn Seibold
Elmar Jentzsch
Susanne Schunk
Alexander Schulze

GREECE

Barbara Kondilis, MSW, MPH
Constantine I. Vardavas, MPH
Yiannis Tountas, MD, MPH
Elisabeth Petsetaki, MPH
Anthony Kafatos, MD, MPH, MSc, PhD
Christine Dimitrakaki, MSc
Eleni Moreti, BA

LAOS

Onechanh Keosavavh, MD
Keooudom Namsena, MD

LEBANON

Natalia Linos

MALAYSIA

Foong Kin, PhD
Razak Lajis, M.Sc.
Rahmat Awang, D.Pharm
Maizurah Omar, PhD

NEW ZEALAND

Nick Wilson MBChB, MPH, FAFPHM
Richard Edwards MBBChir, MRCP, MFPH, MPH, MD
Anthony Maher, BSc
Jenny Näthe
Rafed Jalali

PAKISTAN

Kaneez Zehra
Arshad Ali Syed
Shaheryar Khan

POLAND

Krzysztof Przewozniak, MA
Jakub Gumkowski MA
Marta Przewozniak, BSc
Barbara Wieteska, MSc
Sylwia Kołakowska, MSc
Daniel Pokrywczynski, MA
Janina Fetlinska, PhD
Małgorzata Zagroba, MSc
Pawl Polak, MA

PORTUGAL

Sílvia Menezes

ROMANIA

Florin Dumitru Mihaltan, PhD
Ioana Munteanu, MD

SPAIN

Maria J Lopez
Manel Nebot
Irene Gonzalez
Isabel Marta

SYRIA

Wasim Maziak, MD, PhD
Fouad M Fouad, MD

THAILAND

Stephen Hamann, MPH, EdD
Naowarut Charoenca, Dr.PH
Nipapun Kungskulniti, Dr.PH
Sorakom Santhana, MPH
Chairat Neramit

TUNISIA

Radhouane Fakhfakh, MD
Karim Kammoun, MD
Youssef Slama
Nourredine Achour, MD

UNITED KINGDOM

Richard Edwards, MD
Christian P. Hasselholdt
Kim Hargreaves
Claire Probert
Richard Holford
Judy Hart, MPH
Martie Van Tongeren, PhD
Adrian F.R. Watson, PhD

URUGUAY

Adriana Menéndez , MD

VIETNAM

Nguyen Thi Hoai An, MA
Tran Thi Kieu Thanh Ha, BA
Le Thi Chi Phuong, Dr

References

1) Hoffmann, D., I. Hoffmann, and K. El-Bayoumy, *The less harmful cigarette: a controversial issue. a tribute to Ernst L. Wynder.* Chem Res Toxicol, 2001. **14**(7): p. 767-90.

2) US Department of Health and Human Services, *The health consequences of involuntary smoking. A report of the Surgeon General, 1986*. 1986, Public Health Service, Centers for Disease Control: Rockville, Maryland.

3) US Environmental Protection Agency, *Health Effects of Passive Smoking: Assessment of Lung Cancer in Adults, and Respiratory Disorders in Children*. 1992.

4) National Toxicology Program, *9th Report on Carcinogens 2000*. 2000, U.S. Department of Health and Human Services, National Institute of Environmental Health Sciences: Research Triangle Park, NC.

5) World Health Organization, *Tobacco Smoke and Involuntary Smoking*. 2004, IARC.

6) World Health Organization. WHO Framework Convention on Tobacco Control (WHO FCTC). Accessed 5/30/06; http://www.who.int/tobacco/ framework/en/.

7) Americans for non-smokers' rights. International Activity. Accessed 5/30/06 from Hhttp://www.no-smoke.org/learnmore.php?id=174H.

8) Ott W, Switzer P, Robinson J. Particle concentrations inside a tavern before and after prohibition of smoking: evaluating the performance of an indoor air quality model. J Air Waste Manag Assoc 1996;46:1120-1134.

9) US Environmental Protection Agency. National ambient air quality standards for particulate matter; final rule. Federal Register 1997;62(138):38651-38701

10) Mulcahy M, Clancy L, Connolly G, Carpenter C, Travers M, Cummings KM, Hyland A. How Smoke-free laws improve air quality: a global study of Irish pubs. Health Service Executive-West Environmental Health Department, Galway, Ireland.

11) Environmental Protection Agency. January 2005 Draft Staff Paper for Particulate Matter Fact Sheet. http://www.epa.gov/airlinks/pdfs/pmstaff2_fact.pdfix. Accessed 10/24/2005.

12) Repace JL. An air quality survey of respirable particles and particulate carcinogens in Delaware hospitality venues before and after a smoking ban. In: Repace Associates, Inc.; 2003.

13) Travers MJ, Cummings KM, Hyland A, Repace JL, Pechacek TF, Caraballo R, et al. Indoor Air Quality in Hospitality Venues Before and After the Implementation of a Clean Indoor Air Law – Western New York, 2003. Morbidity and Mortality Weekly Report 53(44), 1038-1041.

14) Hyland A, Travers MJ, Repace JL. 7 City Air Monitoring Study, March-April 2004. Roswell Park Cancer Institute, May 2004.

15) Eisner MD, Smith AK, Blanc PD. Bartenders' respiratory health after establishment of smokefree bars and taverns. JAMA 1998;280(22):1909-14.

16) Sargent RP, Shepard RM, Glantz SA. Reduced incidence of admissions for myocardial infarction associated with public smoking ban: before and after study. BMJ. 2004 Apr 5.

17) Farrelly MC, Nonnemaker JM, Chou R, Hyland A, Peterson KK, Bauer UE. Change in hospitality workers' exposure to secondhand smoke following the implementation of New York's smoke-free law. Tobacco Control. 2005;14:236-241.