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Indoor Air Quality in Hospitality Venues Before and After the Smoking Ban

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Abstract: The objective of our investigation was to assess the changes in the air quality of indoor public places in consequence of the stricter legislation aimed at protecting the non-smoking population. Indoor air quality of hospitality venues in the 8th and 9th districts of the capital was studied, and concentration of particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) was measured with SidePak TSI AM510 Personal Aerosol Monitor.

When smoking was allowed, the mean aerosol concentration (G) had been 393µg/m³ (347-444) in all of the places, which value is nine times higher than the 44µg/m³ (43-45) measured after the ban of smoking in the same places. The findings of the survey have confirmed our assumption unequivocally: the ban on smoking significantly reduces indoor air pollution. In the average $PM_{2,5}$ concentration (G) 89% decrease was observed in all the places studied, after the stricter regulations regarding smoking.

KeyWords: smoking, tobacco smoke, particulate matter, indoor air quality, $PM_{2.5}$

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INTRODUCTION

Tobacco smoke is a toxic mixture containing more than 4,000 gaseous and particulate components many of them are known as carcinogens and toxic substances. Therefore its inhalation damages all organs and organ systems, especially the respiratory and cardiovascular systems. Besides nicotine and carbon monoxide, nitrogen-oxides, polycyclic aromatic hydrocarbons, nitrosamines, formaldehyde, hydrazine, benzene, acrolein and several heavy metals can be found in tobacco smoke. Nicotine has a well known pharmacological effect and probably is the only component liable for addiction, while carbon monoxide, nitrogen-oxides and glycoprotein cause cardiovascular diseases.

In the 27 member states of EU, about 13 million people suffer from one of the six main types of diseases associated with smoking [EU, 2004]. These are:
- Bronchitis and other lower respiratory tract infections
- Chronic obstructive pulmonary disease
- Stroke, heart attack, peripheral arterial diseases and other cardiovascular diseases
- Asthma
- Lung cancer
- Other types of cancer, for example pancreas, oesophagus, and stomach cancer

Due to the adverse effects of tobacco smoke, it is important to measure air pollution in public premises with closed airspace. Because of the complexity of smoke, quantitative measurement of indicator components is applied for air quality investigation. In practice, the mostly examined components are aerosols, carbon monoxide and nicotine but none of them characterize totally the tobacco smoke. Nicotine is a good example for this, which is a specific component of tobacco smoke, but the gas- and solid phase balance is not invariant, and on the other hand, does not correlate with the amount of other smoke ingredients.

The tobacco smoke aerosol contains the essential components of the cigarette (solid-phase nicotine, tars), and after smoking, it remains in the air for a longer period of time.

According to our experience and numerous published data, examination of the different fractions of particulate matters (PM_{10}, $PM_{2.5}$, and PM_1) is eligible to detect the presence of smoke. The concentrations of indoor aerosol particles were significantly higher at those places where smoking was allowed, irrespective of the question whether smoking was allowed only in a section of the place. In a U.S. study the $PM_{2.5}$ level in restaurants and bars was reduced by 90% due to the anti-smoking law. In case of bigger recreation centres 84% improvement was observed and 58% reduction of air pollution was detected in those areas where the smoke came from the neighbouring room (Travers et al., 2003). In a cross-sectional study, 53 catering units in seven major U.S. cities were investigated and indoor air pollution was 82% lower in smoke-free places (Hyland et al., 2004).

15 catering units were monitored in the state of Delaware and in Boston (MA) before and after launching the smoke-free law. It was found that about 90-95% of the particles entering the respiratory tract came from tobacco smoke (Repace, 2004; Repace et al., 2006). In a Hungarian study, also $PM_{2.5}$ concentration was tested in indoor places of several catering units in Budapest and Zalakaros. The $PM_{2.5}$ concentration was 18 times higher in public places where smoking was allowed than in non-smoking places (Tárnoki et al., 2009). In a comprehensive study, using a unified measurement protocol, $PM_{2.5}$ load was examined in different types of catering units in 32 countries. Generally, the $PM_{2.5}$ level was 8.9 times higher (95% CI 8.0 to 10) in those places where smoking was observed than in areas with no smoking (Hyland et al., 2008). Numerous

other studies showed many benefits of smoke-free provisions to the level of indoor air pollution (Mulcahy et al., 2005; Ott et al., 1996).

Smoking bans have a positive effect on health by the reduction of tobacco products consumption and exposure to tobacco smoke. Numerous studies show that reduction in passive smoking is advantageous mostly to workers, especially in the hospitality sector. The bans have a positive impact on the health outcomes as well; the most significant reduction appears in the number of hospital admissions for acute coronary syndrome. Although complete evaluation of the results would require 20-30 years, the data from smoke-free countries are promising.

A survey was conducted in March 2007 (before launching) and July (after launching) in 35 bars in Belfast (Bannon et al., 2009). The results indicated that after introduction of the ban the prevalence of a variety of adverse respiratory symptoms decreased by 1.3-18.6% among smoking employees, and 21.9-33% among non-smoking employees. The incidence of acute coronary syndrome reduced by 17% after the anti-smoking law came into force in Scotland (Pell et al., 2008).

An Italian study (Cesaroni et al., 2008) aimed to estimate the changes in the frequency of acute coronary cases in Rome following the bill that banned smoking in all indoor public places in January 2005. The researchers analyzed the acute coronary cases between 2000 and 2005 (post-hospital deaths and hospital admissions) among Roman citizens at the ages of 35-64 years. After launching the smoking ban, a statistically significant reduction (11.2%) was observed in acute coronary cases of 35-64 year olds (7.9%). Meyers and colleagues (2009) performed a meta-analysis about the cardiovascular effects of smoking bans in public places. They included all published peer-reviewed original studies in their systematic analysis. The risk of AMI incidence decreased overall by 17% after the smoking ban, compared to pre-ban period, the greatest extent was found among young people and non-smokers. A Spanish study (Fernandez et al., 2009) was designed to assess the impact of the smoking ban among hospitality workers. After the ban, the cotinine level of saliva was reduced by 55.6% among those non-smoking workers of the catering units where smoking was completely prohibited ($p < 0.01$). The cotinine concentration decreased by 27.6%, ($p = 0.068$) for those catering establishments workers where smoking is permitted in designated areas, and decreased by 10.7%, ($p = 0.475$) in case of workers whose workplace permitted smoking. In Spain, based on self-reports, the respiratory symptoms decreased significantly in case of smoke-free catering unit workers (71,9%, $p < 0.05$). According to a British study (Sims et al., 2010), the anti-smoking law led to a remarkable decrease of emergency hospital admissions for myocardial infarction. One year after the Act came into force, emergency hospital admission decreased by 1200 cases. It was significant for men over 60 years (3.1% reduction) and for women over 60 years (3.8% reduction). According to a Swiss study (Lukas et al., 2010), a year after introducing the smoking ban law the incidence of acute myocardial infarction decreased by 22%.

On request of the Office of the Chief Medical Officer, our Department participated in the work team whose task was to control and monitor the implementation of the non-smokers protection law. In this framework, in cooperation with the Smoking Focus Point of the National Centre for Health Promotion (NIHD), we developed an investigation program to measure indoor air quality of catering facilities. The aim of our study was to monitor the changes of indoor air quality in relation to the stricter non-smokers protection law. According to the amendment of the Act, the smoking ban applies to all enclosed public premises, as workplace, health care providers, catering establishments, including public institutions, nightclubs, pubs, bars, public transportation, bus stops, underground tunnels used by pedestrians and playgrounds and their 5-foot area as well. Thus, significant improvement could be expected in indoor air quality of various closed public spaces.

We presumed that analysis of the aerosols was the most adequate in both theoretical and practical aspects to determine air pollution caused by smoke. If smoking is present in premises, smoke is the main factor to determine indoor air quality. In the study, particles less than 2.5 micrometers in diameter ($PM_{2.5}$) have been selected as an indicator substance because this dust fraction is very sensitive for indoor smoking. The particle diameters of the smoke coming from burning cigarettes rank in the fine and ultrafine particle range (0.02-2μm) *(Fig. 1)*, and can be inhaled deep into the lungs, and have a number of adverse effects (Klepeis et al., 2003).

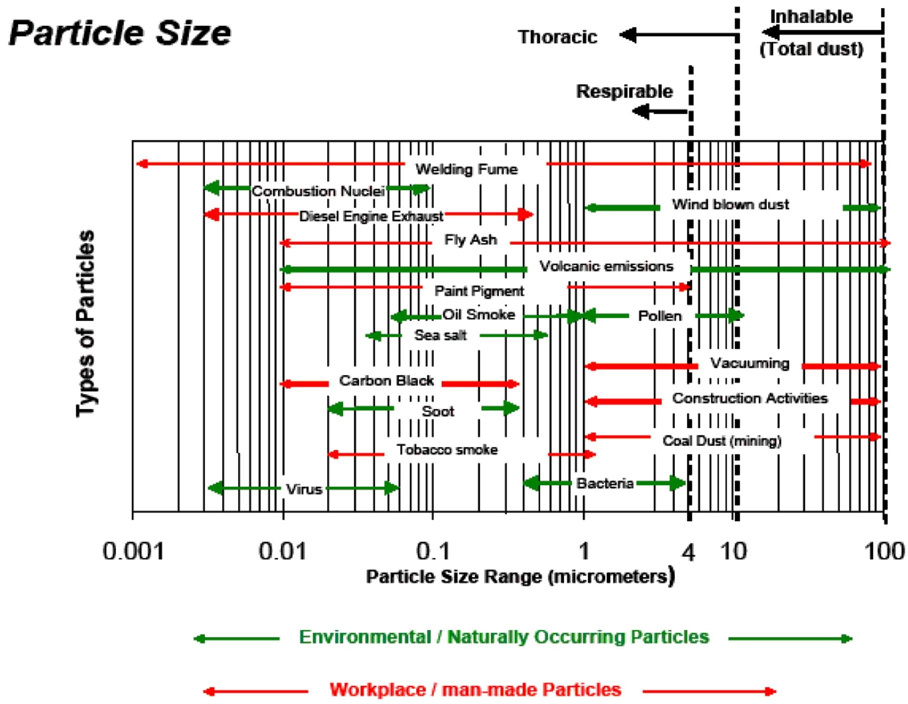

Figure 1. Particle size

Publications with scientific evidence about the effect of particular matter (PM) on the health of urban population from different parts of the world are consistent. The effect has a broad spectrum, it primarily affects the respiratory and circulatory systems, and the effects degree varies depending on age and health condition. The risk of the effects increases according to the exposure and there is not enough evidence that an ineffective threshold concentration exists. The concentration which has an impact on health does not differ significantly from the average concentration measured in air. Epidemiological studies prove that dust evolves its adverse effects in both short and long terms. PM mainly causes local inflammation, followed by the rise of a pre-existing respiratory disease incidence. Fine dust particles get down into the alveoli, starting an inflammatory process in the lung, causing increase in blood clot, leading to clot formation (Committee on the Medical Effects of Air Pollutants, 2006).

Determination of different limit values is a result of a compromise everywhere, which is based on professional and scientific knowledge, local conditions, limited by financial and technical options. World Health Organization (WHO, 2006) has created in its Air Quality Guidelines (AQG) a rating system.

Table 1. WHO air quality guidelines and interim targets for particulate matter (annual mean concentrations)

	PM_{10}	$PM_{2.5}$	Basis for the selected level
Interim target-1 (IT-1)	70	35	These levels are associated with about a 15% higher long-term mortality risk relative to the AQG level.
Interim target-2 (IT-2)	50	25	In addition to other health benefits, these levels lower the risk of premature mortality by approximately 6% [2–11%] relative to theIT-1 level.
Interim target-3 (IT-3)	30	15	In addition to other health benefits, these levels reduce the mortality risk by approximately 6% [2-11%] relative to the -IT-2 level.
Air quality guideline (AQG)	20	10	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to long-term exposure to $PM_{2.5}$

The system classifies *(Table 1)* PM exposure in four categories based on interim target (IT) of concentrations. An increase in mortality levels can be assigned to the IT 1-3 levels compared to the AQG in case of annual and 24-hour exposure as well. If PM exposure corresponds to the highest concentration range (IT-1), mortality is 15% higher, compared to the lowest AQG level regarding an annual exposure. By reducing PM pollution to the level recommended by WHO, mortality and morbidity would measurably decrease (6-15%).

METHODS

The former National Institute of Environmental Health (now: National Public Health Centre, Directorate for Environmental Health), Department of Air Hygiene carried out the measurements with the participation of colleagues from the 6^{th}-7^{th}-8^{th}-9^{th} District Institute of Public Health, Budapest. Five different types of catering units were studied in the 8^{th} and 9^{th} Districts of Budapest.

Method of measurement

Determination of selected dust fraction was carried out by an active sampling method, 1 minute average time and the measuring interval was 1 hour indoor and 10 minutes outdoor.
TSI SidePak AM510 personal aerosol monitor was used for the tests *(Figure 2)*.

Figure 2. TSI SidePak AM510 personal aerosol monitor

The instrument comprises a 2.5 μm impactor and measures the mass concentration of the particles up to 2.5 microns in diameter ($PM_{2.5}$) in the air. The monitor uses light scattering technology to determine the momentary mass concentration *(Figure 3)*.

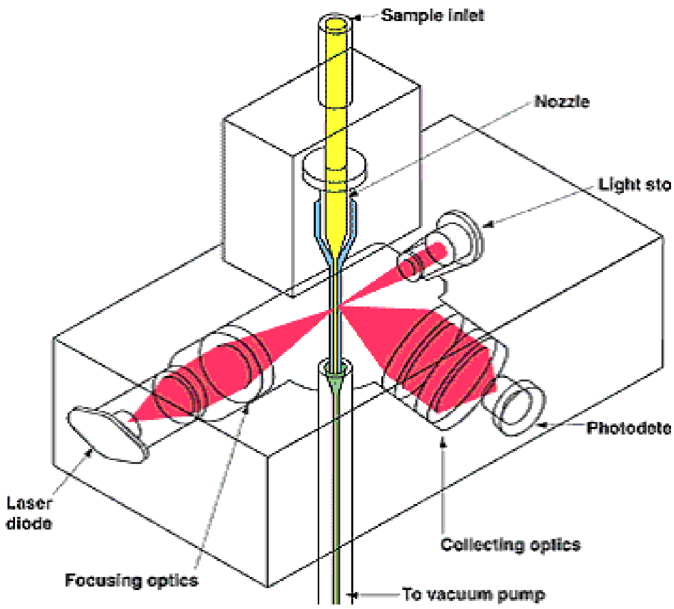

Figure 3. TSI SidePak AM510 personal aerosol monitor theory of operation

The device sucks the air with a flow rate of 1.7 l / min, and passes it continuously through the sensor chamber. The aerosol is illuminated by a thin laser beam and the particles scatter light in all directions. A lens projects the dust particles scattered laser light onto the photo detector. The optic axis is perpendicular to the laser beam and the air flow direction as well. The sensor's circuit creates voltage proportional to light. This voltage is proportional to the scattered light and the aerosol mass concentration. The input voltage value is multiplied by an inner certification constant to get mass concentrations. The internal calibration constant was determined by a known mass concentration test aerosol and the SidePak ™AM510 instrument's voltage relationship.

Schedule of measurements

The tests were carried out in all catering units during the autumn and winter months, when the windows were closed. Measurements were made in two periods:

- ✓ *First measurement period:* before tightening the non-smokers protection law, examining the effects of smoking in smoking area
- ✓ *Second measurement period:* After 1st February 2012 to study the effect of smoking ban on indoor air quality. All of the first period measurements were repeated, but because of the more rigorous law, there was no smoking in catering units.

Sampling points

The following types of hospitality venues were selected for measurements:
- ✓ Restaurant
- ✓ Cold catering kitchen
- ✓ Pub
- ✓ Disco
- ✓ Cafe

Tests were carried out in one of each type of the catering units. $PM_{2.5}$ mass concentration was monitored in one indoor and one ambient sampling point before or after the indoor measurement in each catering unit. The sampling device was positioned to avoid direct exposure (indoor baking, cooking, and candles) to ensure representativity. We took into account the HVAC equipment and the location of doors and windows.

Statistical analysis

For the statistical analysis, geometric means (G) were compared, because the data showed a log-normal distribution. To determine the statistical significance, we applied two-sample Wilcoxon rank-sum (Mann-Whitney) test. During the analysis, $PM_{2.5}$ was the outcome, smoking was the independent variable and it was stratified by restaurant types.

RESULTS

Our main aim was to determine the difference in indoor air $PM_{2.5}$ levels before and after toughening up the Act on the protection of non-smokers. We compared the aerosol concentrations before and after the smoking ban, and we also examined the $PM_{2.5}$ level differences between different types of monitored places. *Table 2* shows the geometric means (G) and confidence intervals (95% CI) of $PM_{2.5}$ pollution in the different types of catering units. It also contains data from ambient air in front of the catering units in both measurement periods.

The average aerosol mass concentration (G) was 393μg/m³ (347-444) concerning all the monitored units while smoking was present, nearly 9-times higher than the result when smoking was not allowed [G: 44μg/m³ (43-45)] in the same places.

In the measurement period when smoking was still allowed in the studied places, the highest level of $PM_{2.5}$ was observed (GH924μg/m³) in the disco, followed by a pub (806μg/m³) and the catering unit with kitchen (748μg/m³). Due to the good air exhaust ventilation, the cold kitchen units and the cafe had a lower $PM_{2.5}$ average concentration (149 and 113μg/m³) during the examined period.

Table 2. Indoor air $PM_{2.5}$ levels before and after tightening up the act on the protection of non-smokers

Sampling points	Smoking	$PM_{2.5}$ level (μg/m^3) geometric averages and 95% CI	Indoor $PM_{2.5}$ ratio (smoking/no smoking)
Disco, indoor	Yes	924 (859-995)	26.4
	No	35 (33-38)	
Disco, outdoor	Yes	20 (13-28)	
	No	24 (22-26)	
Pub, indoor	Yes	806 (739-878)	11.5
	No	70 (68-72)	
Pub, outdoor	Yes	8 (7-9)	
	No	40 (36-44)	
Cold catering kitchen, indoor	Yes	149 (116-192)	3.6
	No	41 (40-43)	
Cold catering kitchen, outdoor	Yes	7 (6-9)	
	No	37 (34-40)	
Cafe, indoor	Yes	113 (91-139)	2.9
	No	39 (38-41)	
Cafe, outdoor	Yes	7 (6-9)	
	No	37 (34-40)	
Restaurant, indoor	Yes	748 (721-776)	18.2
	No	41 (40-43)	
Restaurant, outdoor	Yes	20 (15-25)	
	No	27 (23-30)	
Indoor, total	Yes	393 (347-444)	8.9
	No	44 (43-45)	
Outdoor, total	Yes	11 (9-13)	
	No	32 (30-34)	

$PM_{2.5}$ levels measured in the second measurement period clearly proved that smoking ban had a good effect on indoor air quality. Aerosol pollution at a much lower level was typical in most of the monitored catering units (G: 35-41μg/m³) after the smoke-free law. We experienced the highest average values in the pub (G: 70μg/m³) *(Figure 4)*.

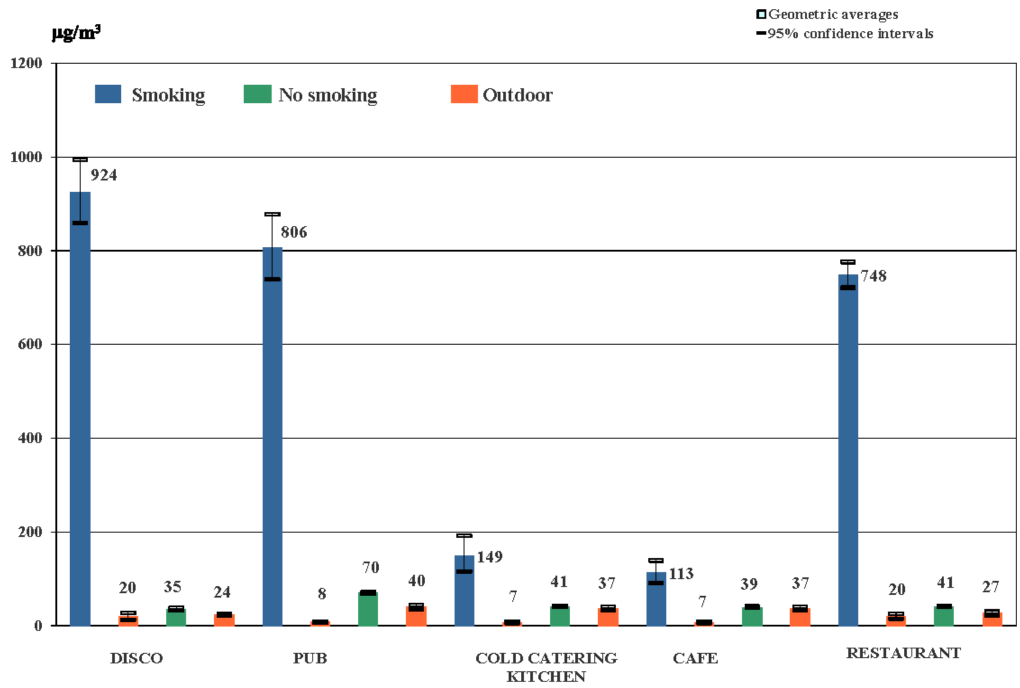

Figure 4. Geometric mean for $PM_{2.5}$ of monitored catering units by type

To compare the results of the two measurement periods, we can establish that the average $PM_{2.5}$ levels - either at all investigated places or one by one - were significantly ($p < 0.001$) higher before the introduction of smoke-free regulations than after that.

The aerosol particles arithmetic mean concentration was 12-26 times higher in the case of disco, pub and restaurant, while it was 3-4 times higher in the relatively less loaded cold kitchen unit and cafe when smoking was still allowed in indoor places, opposed to when smoke was not present. We illustrated the temporal changes in $PM_{2.5}$ concentration for both measurement periods in *Figures 5a-e*.

We demonstrated also the outside $PM_{2.5}$ levels (in front of the catering units). Based on the figures we can say that before the smoking ban, the indoor $PM_{2.5}$ momentary concentration fluctuated depending on the extent of smoking. However, when tobacco smoke was not present in the air, the amount of aerosol particles was nearly the same level during the measurement.

We experienced significantly higher $PM_{2.5}$ levels in the monitored indoor places than in ambient air when smoking was allowed in indoor places. Regarding to all of the places, the indoor $PM_{2.5}$ geometric mean level (G = 393μg/m³) was 36 times higher than the outdoor one (G = 11μg/m³) before introduction of the smoking ban provision.

The biggest difference in $PM_{2.5}$ levels (G) was found in the pub, where catering unit's aerosol pollution was more than 100 times higher than the measured outdoor values. In case of the disco and hot kitchen, there was a significant difference between indoor and outdoor average $PM_{2.5}$ concentrations. We found 46 and 37 times higher $PM_{2.5}$ levels in the mentioned catering units, respectively, than in outdoor air. The higher indoor pollution usually indicates the presence of an indoor source.

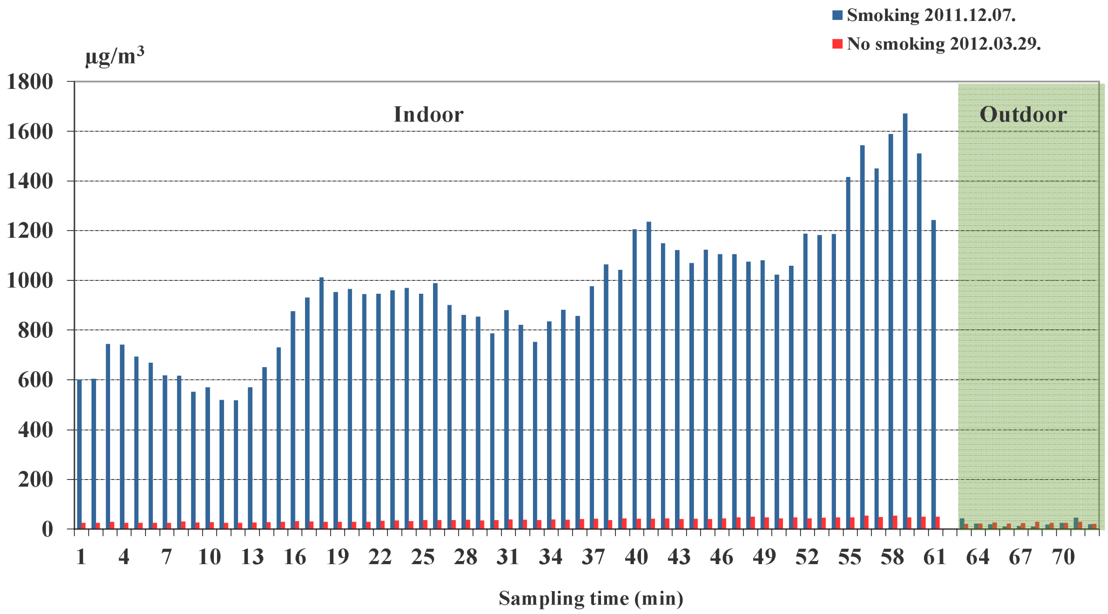

Figure 5a. The temporal changes in $PM_{2.5}$ concentration ($\mu g/m^3$) before and after tightening up the act on the protection of non-smokers, in case of disco

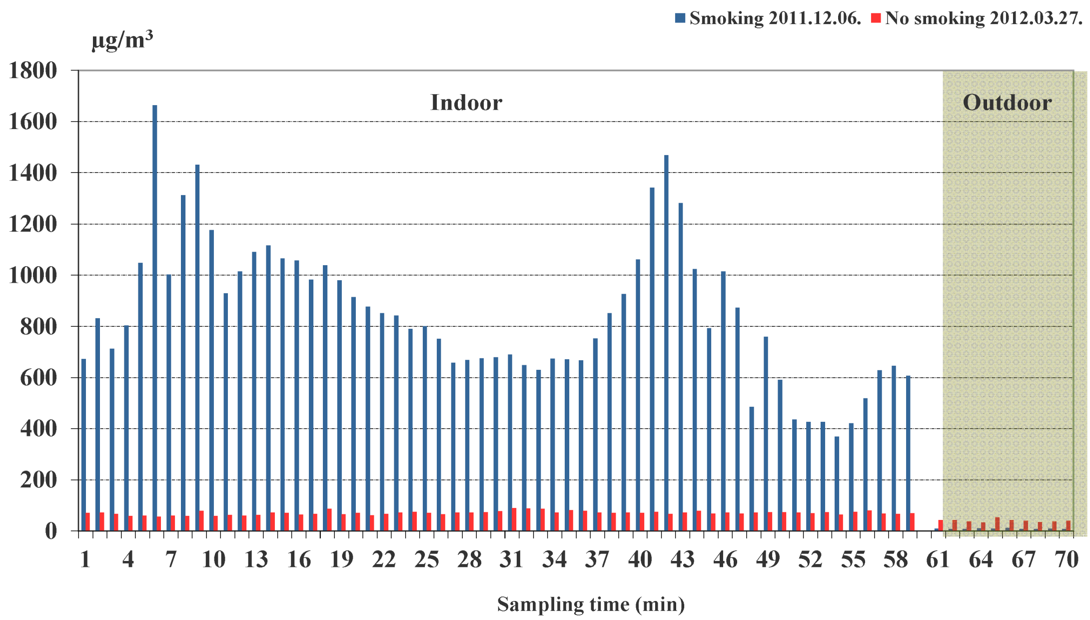

Figure 5b. The temporal changes in $PM_{2.5}$ concentration ($\mu g/m^3$) before and after tightening up the act on the protection of non-smokers, in case of pub

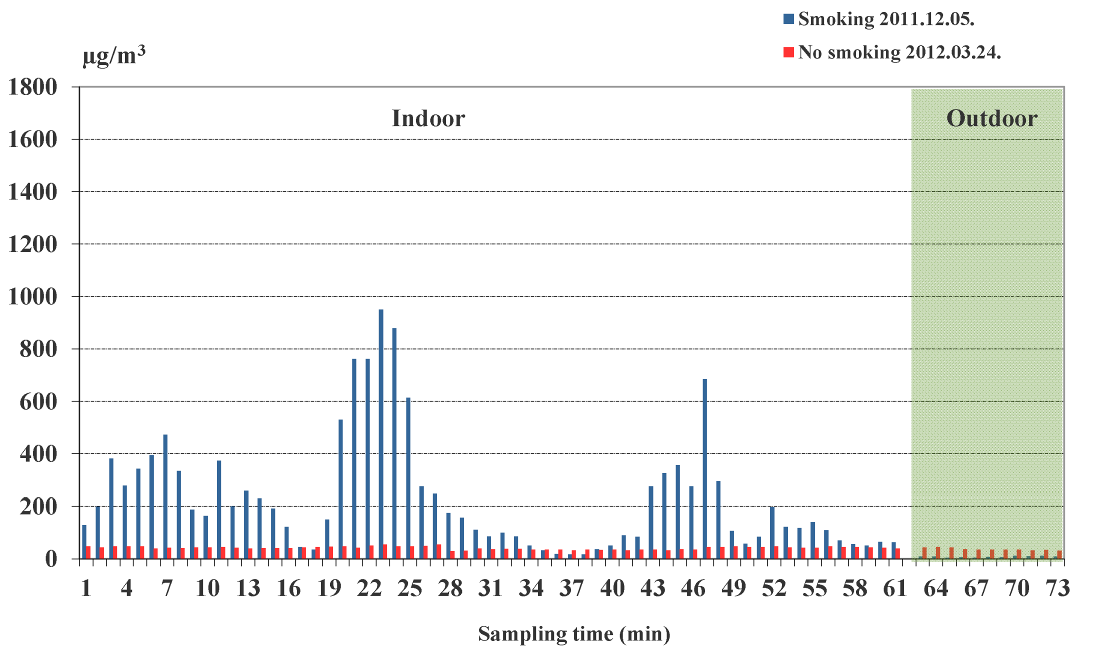

Figure 5c. The temporal changes in $PM_{2.5}$ concentration ($\mu g/m^3$) before and after tightening up the act on the protection of non-smokers, in case of cold catering kitchen

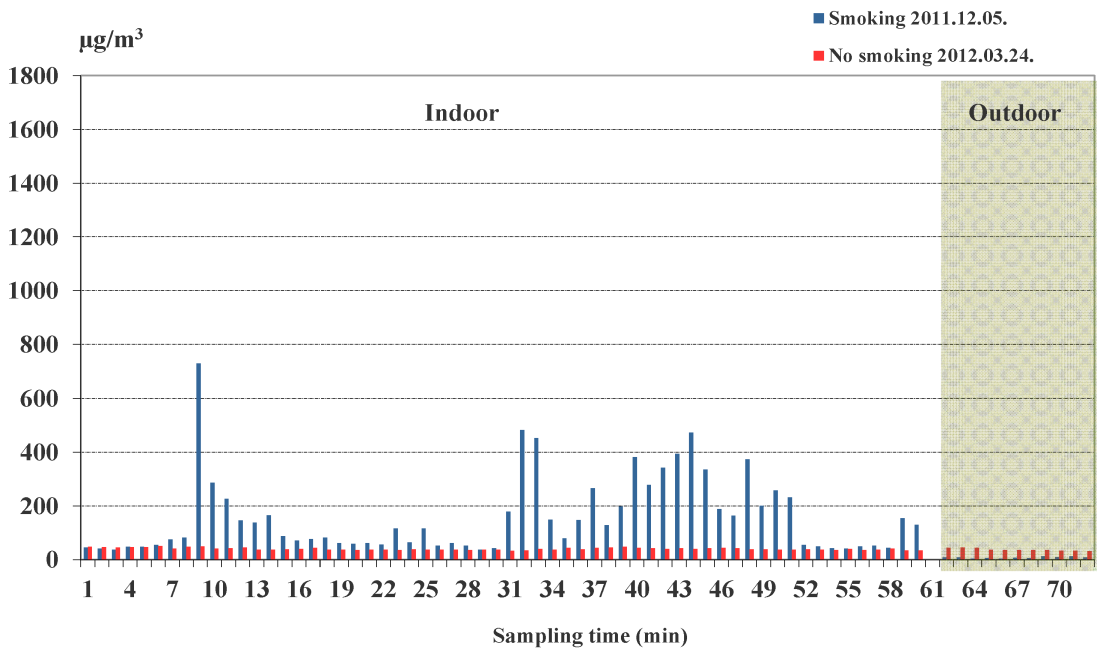

Figure 5d. The temporal changes in $PM^{2.5}$ concentration ($\mu g/m^3$) before and after tightening up the act on the protection of non-smokers, in case of Cafe

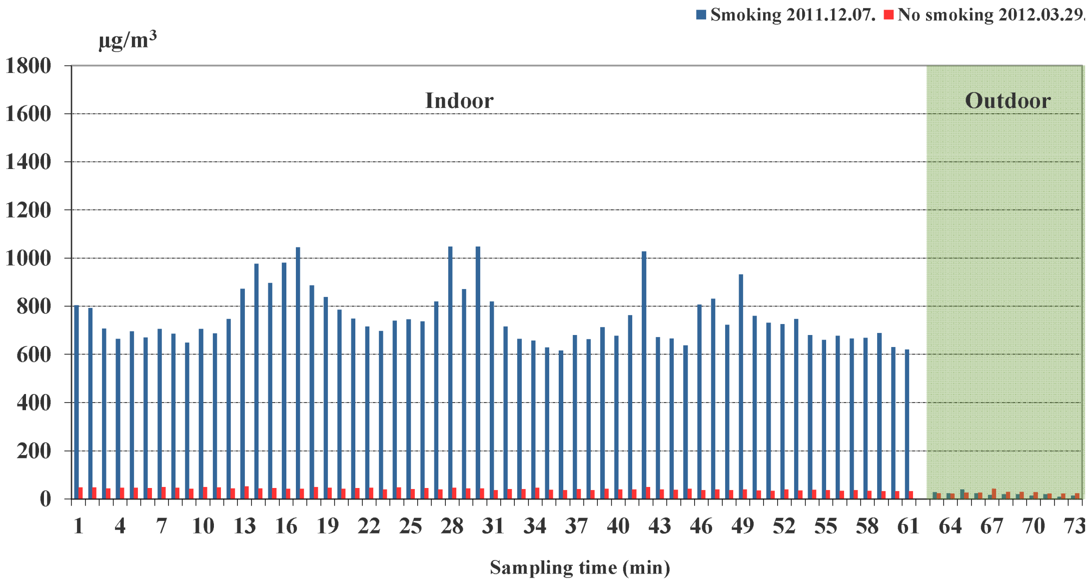

Figure 5e. The temporal changes in $PM_{2.5}$ concentration ($\mu g/m^3$) before and after tightening up the act on the protection of non-smokers, in case of restaurant

In the second measurement period, after tightening the law on the protection of non-smokers, the aerosol pollution of the examined indoor places was 1.1-1.8 times higher than the outdoor $PM_{2.5}$ level. This clearly demonstrates that the experienced high aerosol concentration in the catering units before the ban period was caused by tobacco smoke.

DISCUSSION

The results of the survey clearly confirmed our presumption that tightening of the smoke-free regulation was expected to improve the indoor air quality significantly. The examined mass concentration of particles up to 2.5 microns was significantly ($p < 0.001$) higher in all investigated catering establishments when smoking was present. We found that after the tightening of the Act on the protection of non-smokers the average $PM_{2.5}$ concentration **decreased by 89%**. In places where tobacco smoke concentration was very high: the disco, the pub, and the restaurant, the average $PM_{2.5}$ concentration (G) **decreased by 91-96%** after the indoor smoking ban. In case of cold kitchen and café, where tobacco smoke concentration was lower, a **65-72% improvement** of indoor air quality was observed. The outdoor $PM_{2.5}$ reference results demonstrated that in the tested indoor places the cigarette smoke was a highly significant source of the high $PM_{2.5}$ concentrations.

CONCLUSION

Smoking is one of the most important causes of avoidable mortality. The standardized index of smoking related mortality in the EU countries have shown decreasing tendency during the past few decades. Hungary is one of the countries, where smoking caused death is the highest (also in 2009), and the reduction is very slow. The latest survey by OEFI (2012) showed that 30% of the young adults (18-24 years) smoked daily (3% occasionally). The proportion of daily smokers was 32% in the 35-64 year old population. By tightening the law on the protection of non-smokers, Hungary is also complying with the European Union and the WHO's health policy and the professional expectations. Our results showed that indoor air quality improved significantly when smoking was banned and the $PM_{2.5}$ level decreased in indoor places. Owing to the anti-tobacco smoke policy, reduction of active and passive smoking may significantly decrease the public health and economic harm caused by tobacco. The smoking ban may also be beneficial for smoking cessation and can reduce the amount of smoked cigarettes as well.

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