

Fine and Ultrafine Particle Pollution Before and After a Smoking ban in the Catering Industry in Vienna

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Abstract

In the catering industry tobacco smoke was the primary source of fine and ultrafine particles, which are well known for their health-damaging effects. As shown in studies, attempts to reduce passive smoking in the catering industry of Vienna, like separated smoking rooms, failed to reduce fine and ultrafine particle concentrations effectively. On November 1st 2019, an enlarged non-smoker's protection law was introduced, including a total smoking-ban in the catering industry. 40 hospitality venues with areas for smokers and non-smokers before the ban had been selected as typical Viennese cafes, pubs, bars and discotheques to be sampled unannounced. Concentrations of fine particle mass (PM₁₀, PM_{2.5}, PM₁) and ultrafine particle number (PNC) and lung deposited surface area (LDSA) could be measured before and after the introduction of the smoking-ban in 39 venues at nearly identical locations and under comparable circumstances. Results showed a statistically significant decline in both fine and ultrafine particle concentrations in the former smoking areas for all parameters as well as in the former non-smoking areas for PM_{2.5}, PM₁ and LDSA. After the ban concentrations in former smoking areas and non-smoking areas showed no significant differences any more. From these results the smoking-ban successfully removed particles from breathing air of guests and staff, however, some outliers in the study after the ban point to the necessity of repeated controls in Vienna. Also, outside Vienna the compliance with the law should be controlled in the Austrian hospitality industry.

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Introduction

Fine and ultrafine particles as atmospheric aerosols contribute to hazardous air pollution, mainly deriving from anthropogenic burning processes such as combustion engines, industry, heating and tobacco smoking. [1] Whereas concentrations of fine particles are classified by their aerodynamic diameter as particulate matter $\leq 10 \mu\text{m}$ (PM10), particulate matter $\leq 2.5 \mu\text{m}$ (PM2.5) and particulate matter $\leq 1 \mu\text{m}$ (PM1), [2, 3] concentrations of ultrafine particles are classified by their number (Particulate Number Concentration, PNC) as well as their effective surface (Lung Deposited Surface Area, LDSA). [4]

Studies have shown that fine and ultrafine particles cause multiple negative effects on human health. [5-8] The tinier a particle's diameter, the more easily is its movement into the deeper airways, implying a greater damage potential. [9] Acute, subacute and long-term effects of exposure to high concentrations of fine particles result in higher morbidity, hospital admissions and higher mortality. [2, 7, 8]

One of the most common sources of fine and ultrafine particles in closed spaces is tobacco smoke. [10-12] Preventively, the World Health Organisation (WHO) has formulated guidelines to limit the ambient pollutant concentrations of fine particles. Hence, in a 24-hours-mean, PM10 is limited to $50 \mu\text{g}/\text{m}^3$ and PM2.5 to $25 \mu\text{g}/\text{m}^3$. In a yearly mean, PM10 is limited to $20 \mu\text{g}/\text{m}^3$ and PM2.5 to $10 \mu\text{g}/\text{m}^3$. The WHO has proposed to deploy these restrictions for closed spaces as well. However, concentration limits of ultrafine particles as well as PM1 have not been suggested yet. [3]

Concerning the WHO's suggestions, guidelines for ambient fine particle concentration limits were introduced in Austria. Thus, limited daily means of fine particle concentration were set for PM10 to $50 \mu\text{g}/\text{m}^3$, limited yearly means for PM10 to $40 \mu\text{g}/\text{m}^3$ and for PM2.5 to $25 \mu\text{g}/\text{m}^3$. For PM2.5, no daily mean concentration limit has been set yet. Also, there have neither been guidelines for ultrafine particle concentration or PM1 nor suggestions of concentration limits in closed spaces. [10, 13]

To protect non-smokers from passive smoke in the catering industry, the Austrian legislation requested with 1st January 2009 among other things separated

smoking and non-smoking areas in gastronomic facilities larger than 80m^2 . [14] Nevertheless, as smoking had still been permitted in the smoking areas and experience has shown that separation of the areas was not performed as thoroughly as demanded, doubts of meeting the concentration limits were raised, whereas a study was launched by the Medical University of Vienna from April to October 2019. In this study, two students measured the concentration of fine and ultrafine particulate matter of passive smoke in 40 randomly chosen gastronomic venues, comparing the smoking to the non-smoking area. Results of this study have shown that in spite of separated areas, in many facilities it had not been possible to meet the Austrian guidelines, much less the WHO's suggestions, due to passive smoke. [11, 12, 14]

Alongside, after years of debates, Austria's legislation enlarged the so-called "Non-Smoker's Protection Law" on November 1st 2019, introducing a smoking-ban regarding the whole catering industry. Through this law, all kinds of smoking got prohibited indoors. Furthermore, all gastronomic locations have to mark themselves visibly as smoke free. [15]

On account of this enlarged law, this study is rested. Therefore, its aim is to compare the concentrations of fine and ultrafine particulate matter before to after introducing the smoking ban into Austrian gastronomy, differentiated between formerly smoking and non-smoking areas. Thus, a repeated cross-sectional study on a sample of hospitality venues was created.

Materials and Methods

As to collect samples of fine and ultrafine particle concentration before introducing the smoking-ban, first study measurements were performed from April to October 2019 in 40 randomly chosen, well frequented catering facilities of different types, such as pubs, restaurants, bars, discotheques and cafeterias in Vienna. [11] From November 2019 to March 2020, the measurements were repeated, visiting the same venues considering approximately similar settings, including the same rooms, related time of the recordings and similar weekdays (differencing between days during a week and the weekend), however, to well frequented times (cafes in the afternoon, discotheques at night). One venue of the first study had to be excluded in the second study,

because it was closed, whereas recordings were taken in 39 gastronomy facilities before COVID-19 shutdown started. Each facility had separate smoking and non-smoking areas before November 2019, hence in each area a measurement was undertaken. Each recording lasted 20-30 minutes and, such as to avoid selection bias from permission, was unannounced and hidden while consuming. As devices, GRIMM® Aerosol Spectrometer 1.108 for fine particulate matter, detecting particles bigger than 300 nanometres, and MiniDiSC®, detecting particles of 10-300 nanometres in diameter, for ultrafine particulate concentration were chosen. Measurement methods were described earlier. [16-19]

After collecting the data, the differences of concentrations between these two (formerly) areas were analysed and the differences of concentrations before to after introducing the smoking ban. The various mean concentrations of both studies were compared using statistics, including primarily paired t-testing as well as visual descriptions like boxplots via IBM SPSS Statistics Subscription®. The results were assessed to a confidence interval of 95%, therefore, contrasted against the significance level of $p=0.05$.

Results

Contrasted against $p=0.05$, statistics show statistically significant declines of fine particle concentrations of PM₁₀, PM_{2.5} and PM₁ in former smoking areas as well as of PM_{2.5} and PM₁ in former non-smoking areas, as shown in Table 1 and Figure 1. As for ultrafine particle concentration, statistically significant declines of PNC were registered in former smoking areas. In former non-smoking areas, the PNC decline was not significant. Considering LDSA, in both areas statistically significant declines were shown (Table 2, Figure 2, 3).

Fine and ultrafine particle concentrations after introducing the smoking ban were not significantly different between the former smoking and former non-smoking areas. (Table 3 and 4, Figures 4-6)

Overall, concerning the comparison before to after the introduction of the smoking-ban, in each area were found remarkable declines of fine as well as ultrafine particle concentrations, statistically significant in smoking areas for PM₁₀, PM_{2.5}, PM₁, PNC and LDSA and in non-smoking areas for PM_{2.5}, PM₁ and LDSA. No statistically significant declines were registered in

non-smoking areas for PM₁₀ and PNC. After the ban, there were no significant differences of concentrations found anymore between former smoking and non-smoking areas.

Discussion

In comparison to the smoking areas before the ban statistically significant declines of fine and ultrafine particle concentrations indicate reduced passive smoking in the Viennese hospitality industry, which is a successful development. Also, these results underline the effectiveness of the new legislation to protect the population against the harmful effects of fine and ultrafine particles from second-hand smoke. The decline of PM₁₀ in former non-smoking areas was not significant, which might be due to renovation and other sources of PM₁₀, stirred up and resuspended by walking of guests and waiters. The high variance of PNC in the non-smoking area might have been due to illegal smoking shortly before the air sample was taken, which could explain some very high concentrations at single venues, especially if concomitant with high LDSA and PM₁ in the room. But the big variance of PNC in the non-smoking area could partly be explained also by other possible combustion (e.g. candles which have been excluded at the table of the researcher only) and condensation products, highly variable in time and space.

Prior to the smoking ban indoor smoke exposures were highest in the smoking rooms, followed by adjacent rooms and lowest outdoors. There were no significant differences in concentrations between the smoking and non-smoking areas after the smoking ban entered into force. Therefore, one could diagnose that the indoor air quality was considerably improved. [11, 12] However, some outliers in this study after the ban show the necessity of repeated controls in Vienna. Also, outside Vienna the compliance with the law should be controlled in the Austrian hospitality industry. The goal should be the enforcement of the law in all hospitality venues, complete disappearance of ash trays indoors and at the entrance, indoor air concentrations of PM_{2.5} below 25 $\mu\text{g}/\text{m}^3$ [3] and PNC below 10,000 pt/cm^3 [18].

Limitations and Strengths

Throughout the repeated cross-sectional study on a sample of hospitality venues, most venues could be

Table 1. t-Test with paired samples before and after smoking-ban (PM10, PM2.5, PM1)

					95% confidence interval of differences		T	df	Sig. (2-sided)
		Mean	Standard deviation	Standard error of mean	Lower value	Upper value			
Pair 1	beforeSPM10 - afterSPM10	119.034	149.816	24.303	69.791	168.278	4.898	37	0.000
Pair 2	beforeNSPM10 - afterNSPM10	22.411	68.427	11.566	-1.094	45.917	1.938	34	0.061
Pair 3	beforeSPM2.5 - afterSPM2.5	121.006	136.585	22.157	76.112	165.901	5.461	37	0.000
Pair 4	beforeNSPM2.5 - afterNSPM2.5	29.557	70.819	11.971	5.230	53.885	2.469	34	0.019
Pair 5	beforeSPM1 - afterSPM1	106.264	122.758	20.181	65.335	147.195	5.265	36	0.000
Pair 6	beforeNSPM1 - afterNSPM1	25.982	61.699	10.429	4.788	47.177	2.491	34	0.018

Key: "Before" indicates samples before the introduction of the smoking-ban, "after" after the introduction. "S" codes the smoking area, "NS" the non-smoking area. PM10, PM2.5 and PM1 code the particular fine particle concentration. The hyphen represents the comparison. N = 39

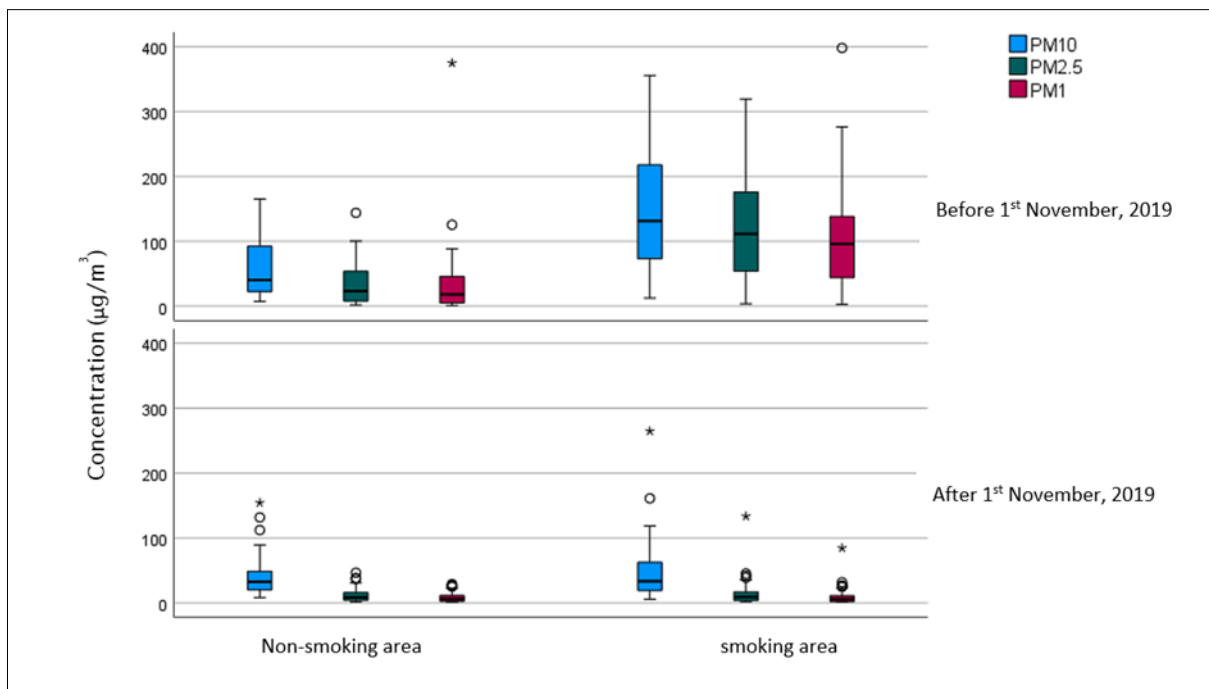


Figure 1. Fine particle mass PM10, PM2.5 and PM1 ($\mu\text{g}/\text{m}^3$) in 39 hospitality venues before and after introducing the smoking-ban in all areas. Outliers are indicated by circles (1.5-3.0 x IQR) and stars (>3.0 x IQR).

Table 2. t-Test with paired samples before and after smoking-ban (PNC, LDSA)

					95% confidence interval of differences		T	df	Sig. (2-sided)
		Mean	Standard deviation	Standard error of mean	Lower value	Upper value			
Pair 1	beforeSPNC - afterSPNC	76724.690	84008.941	14850.823	46436.234	107013.140	5.166	31	0.000
Pair 2	beforeNSPNC - afterNSPNC	3518.939	49925.829	8207.756	-13127.161	20165.040	0.429	36	0.671
Pair 3	beforeSLDSA - afterSLDSA	384.810	332.852	58.841	264.804	504.816	6.540	31	0.000
Pair 4	beforeNSLDSA - afterNSLDSA	67.879	157.620	25.913	15.326	120.432	2.620	36	0.013

Key: "Before" indicates samples before the introduction of the smoking-ban, "after" after the introduction. "S" codes the smoking area, "NS" the non-smoking area. PNC and LDSA code the particular ultrafine particle subsets. The hyphen represents the comparison. N = 39

Table 3. t-Test with paired samples comparing areas after smoking ban (PM10, PM2.5, PM1)

					95% confidence interval of differences		T	df	Sig. (2-sided)
		Mean	Standard deviation	Standard error of mean	Lower value	Upper value			
Pair 1	afterSPM10 - afterNSPM10	7.444	40.982	7.028	-6.855	21.743	1.059	33	0.297
Pair 2	afterSPM2.5 - afterNSPM2.5	4.957	19.183	3.290	-1.736	11.651	1.507	33	0.141
Pair 3	afterSPM1 - afterNSPM1	3.210	11.528	1.977	-.8121	7.233	1.624	33	0.114

Key: "After" represents samples after the introduction of the smoking-ban. "S" codes the smoking area, "NS" codes the non-smoking area. PM10, PM2.5 and PM1 code the particular fine particle concentration. The hyphen represents the comparison. N = 35

Table 4. t-Test with paired samples comparing areas after smoking ban (PNC, LDSA)

					95% confidence interval of differences		T	df	Sig. (2-sided)
		Mean	Standard deviation	Standard error of mean	Lower value	Upper value			
Pair 1	afterNSPNC - afterSPNC	6167.783	28884.296	5273.527	-4617.790	16953.357	1.170	29	0.252
Pair 2	afterNSLDSA - afterSLDSA	-1.748	61.225	11.178	-24.610	21.114	-0.156	29	0.877

Key: "After" represents samples after the introduction of the smoking-ban. "S" codes the smoking area, "NS" codes the non-smoking area. PM10, PM2.5 and PM1 code the particular fine particle concentration. The hyphen represents the comparison. N = 30

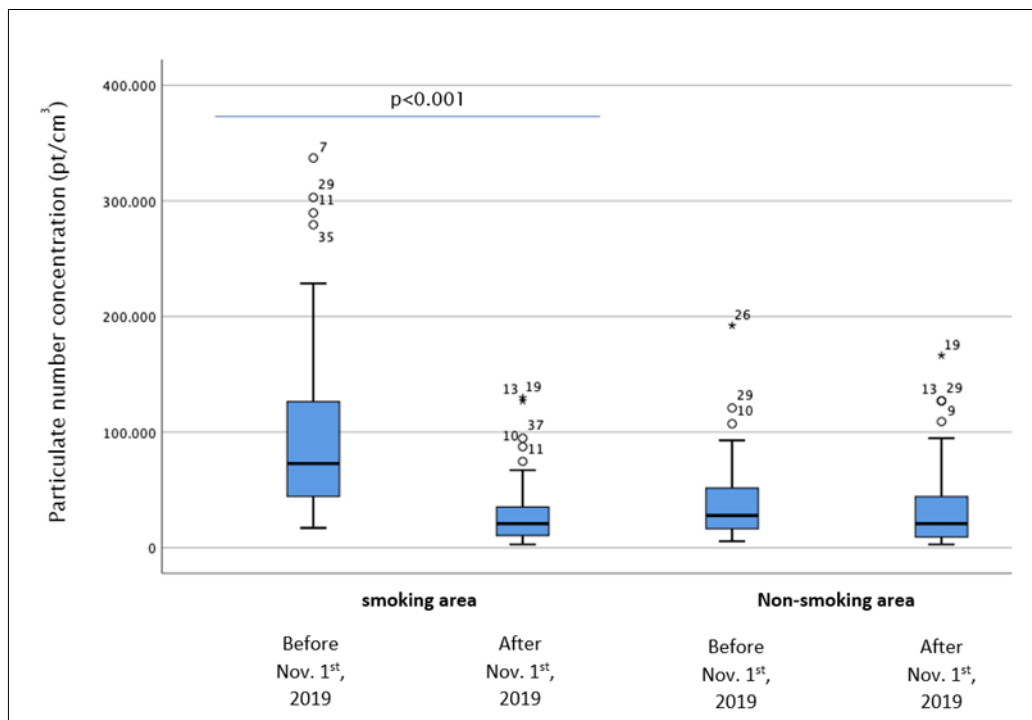


Figure 2. Ultrafine particle number concentration/cm³ in 39 venues before and after introducing the smoking-ban, by areas. Significant differences indicated by $p < 0.001$, outliers indicated by circles (1.5-3.0 x IQR) and stars (>3.0 x IQR).

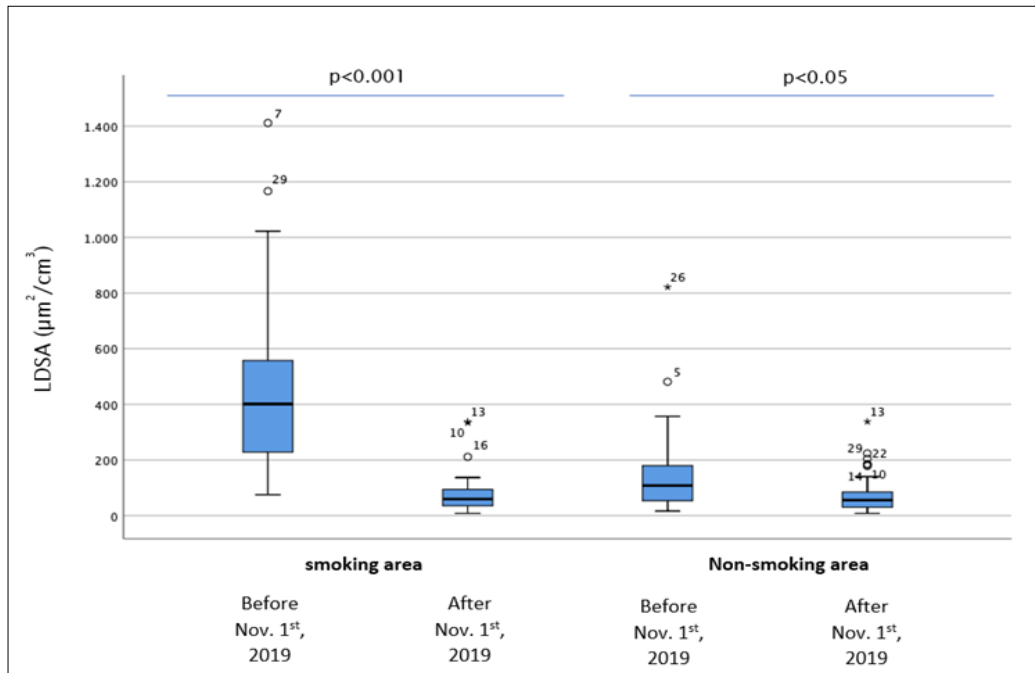


Figure 3. Ultrafine particle surface (LDSA) concentrations ($\mu\text{m}^2/\text{cm}^3$) before and after introducing the smoking-ban, by areas. Significant differences indicated by $p < 0.01$ and $p < 0.05$, outliers indicated by circles ($1.5\text{-}3.0 \times \text{IQR}$) and stars ($>3.0 \times \text{IQR}$).

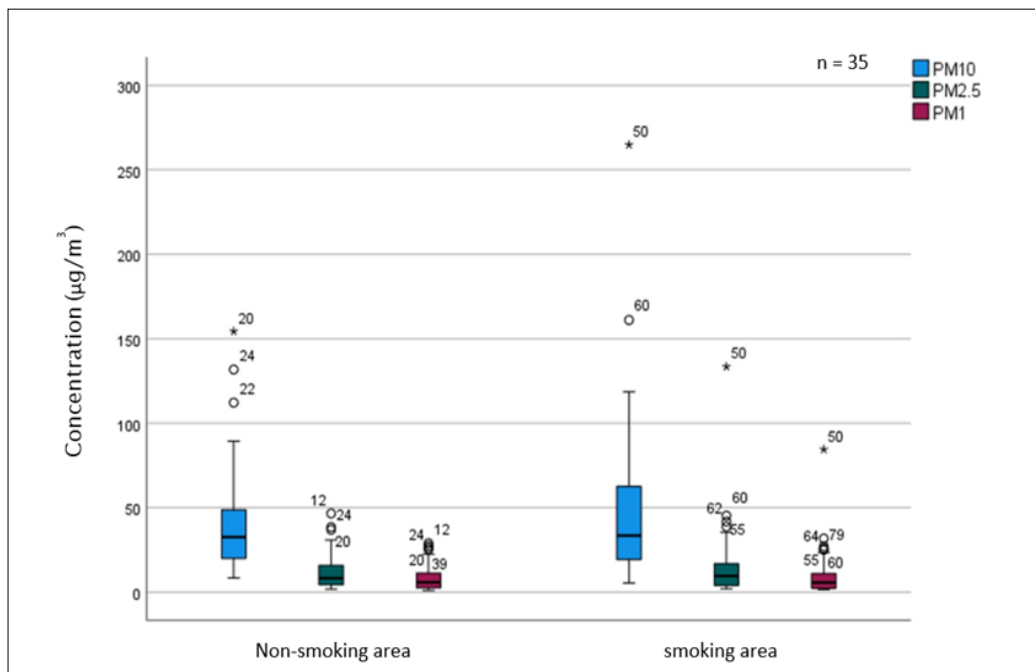


Figure 4. Fine particle mass PM10, PM2.5 and PM1 concentrations in formerly separated areas after introduction of the smoking-ban. Outliers indicated by circles ($1.5\text{-}3.0 \times \text{IQR}$) and stars ($>3.0 \times \text{IQR}$).

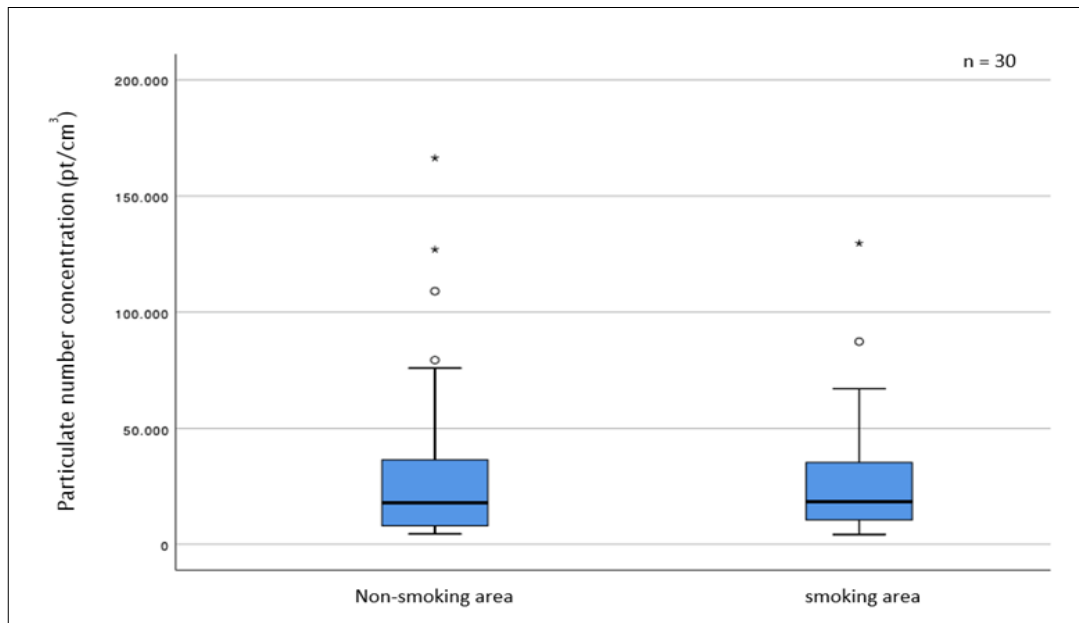


Figure 5. PNC in formerly separated areas after introduction of the smoking-ban. Outliers indicated by circles (1.5-3.0 x IQR) and stars (>3.0 x IQR).

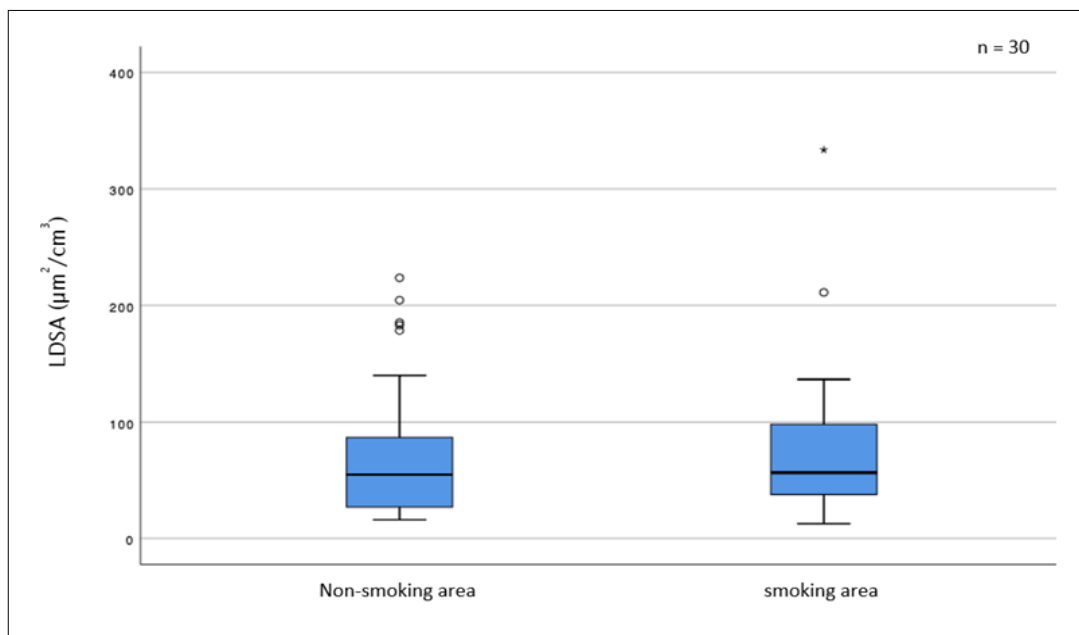


Figure 6. LDSA concentrations in formerly separated areas after introduction of the smoking-ban. Outliers indicated by circles (1.5-3.0 x IQR) and stars (>3.0 x IQR).

visited a second time before the COVID-19 epidemic reached Vienna. Nevertheless, some venues had been adjusted meanwhile to the new law by removing barriers between the former smoking and non-smoking area. Some rooms had also been closed and the sample could not be taken anymore at the same location. Further studies are proposed after lockdowns for COVID-19 ended. By future studies with larger sample sizes, more precise data of the air quality in the catering industry after the smoking-ban could be collected, including chemical analyses of remaining SHS and THS. Moreover, possible confounding factors could be investigated more sensitively.

A strength of this study is that the results showed a high statistical significance, despite of the small sample size. As the samples were taken without any advance-notice, it could be ensured that the results have not been distorted by selection bias from participation. This is a strength for gaining chance samples of true exposures in busy venues, but on the other hand masked sampling did not allow measurements of ventilation, etc. before and after the smoking ban. However, sampling time, sampling location and visual inspection indicated comparable environmental conditions at first and second visit, except for renovated venues or rooms which were excluded from the comparisons. Unannounced and hidden sampling while consuming a drink in central parts of venues, omitting sinks (near open doors and windows) and sources of tobacco smoke (smoker at the same table) was a strategy used before [10] and proved to be successful to differentiate particulate pollution in smoking rooms, adjacent non-smoking rooms, and non-smoking venues [10, 20]. Here it was applied for the first time in Austria on each venue in the same location before and after the smoking ban at comparable day of week and time of day (busy hours). Studies on air quality allow quick estimates of compliance to indoor smoking bans [21,22]. Future studies should use indicators of individual exposure like cotinine, which allow better estimations of health effects [23].

Conclusion

To conclude, by this study's statistics and interpretation the suggestion of the smoking-ban's effectiveness on Viennese gastronomy is given.

Additional controls are necessary to verify compliance with tobacco legislation in the Austrian catering industry.

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Conflicts of Interest

None.

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Author Contributions

Conceptualization, M.N.; data collection and analysis, A.K.S. and A.M.S; writing—original draft preparation, A.K.S. and A.M.S; writing—review and editing, A.K.S and M.N.; visualization, A.K.S. and A.M.S; supervision, project administration, funding acquisition, M.N. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

Not applicable. Due to taking measurements of fine and ultrafine particle concentrations exclusively as well as not using either personalised data nor involving any other beings in this study, it could be desisted from any ethical requests. Apart from the risk of polluted air to the study team, no risky issues were found in this study. All maintained data, e.g. the addresses or names of the monitored facilities, were kept secret by the study's team members.

Data Availability Statement

Data supporting reported results can be found in <https://repositorium.meduniwien.ac.at>, except for

personal ones protected by data protection law, which cannot be deposited in publicly archived datasets.

Abbreviations

IQR = Interquartile range

PM10 = Particulate Matter $\leq 10 \mu\text{m}$ aerodynamic diameter

PM2.5 = Particulate Matter $\leq 2.5 \mu\text{m}$ aerodynamic diameter

PM1 = Particulate Matter $\leq 1 \mu\text{m}$ aerodynamic diameter

PNC = Particulate Number Concentration

LDSA = Lung Deposited Surface Area (alveolar)

SHS = Second hand smoke

THS = Third hand smoke

WHO = World Health Organisation

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