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IMPACTS OF VENTILATION: STUDIES ON "BEFORE AND AFTER" A SMOKING BAN IS IMPLEMENTED

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Abstract. A number of legislative bodies in Europe have already made or are currently considering making policy decisions on the issue of smoking in public places. Policy alternatives have been discussed in Town and Country Planning (2002). In the last decade, the scientific evidence relating to this debate has been reported in a diverse range of publications such as the British Medical Journal, Indoor Air and The Chartered Institution of Building Services Engineers journal. On inspection much of this reporting concludes negatively on the performance of ventilation systems. In this paper, a critical review is undertaken of the "before and after smoking ban" study papers. This paper aims to critically review the findings of these studies in relation to ventilation and draw some working conclusions from these studies.

Keywords: ventilation systems, environmental tobacco smoke, before and after a smoking ban, legislation, policy.

1. Introduction

A number of legislative bodies in Europe have already made or are currently considering making policy decisions on the issue of smoking in public places. Policy alternatives have been discussed in Town and Country Planning (Jones *et al.* 2004). In the last decade, the scientific evidence relating to this debate has been reported in a diverse range of publications such as the British Medical Journal (BMJ), Indoor Air and the Chartered Institute of Building Services Engineers (CIBSE) Journal. On inspection much of this reporting concludes negatively on the performance of ventilation systems (Mulcahy, Repace 2000; Carrington *et al.* 2002, 2003; Gee *et al.* 2005, 2006; Kotzias *et al.* 2004).

Where introduced, smoking bans usually identify a number of specific exemptions, for example prisons and long stay psychiatric care homes, and it is important that these spaces are ventilated using the best technologies available in order to protect both user groups and staff employed in these buildings (Geens 2008). The most immediate health and safety concern from smoking in such buildings is probably that of fire with the risk of smokers falling asleep in their rooms whilst smoking. This risk is reduced by providing a centralised smoking room which is more easily monitored than individual rooms. The same strategy facilitates easier management of longer term health and safety concerns about the exposure of staff to environmental tobacco smoke (ETS). The use of ventilation to prevent migration of ETS through the building and to dilute ETS in the smoking room is more readily and economically managed if smoking is limited to one room. This technique already is used very effectively in infection control in hospitals (Geens 2008). Ironically, many in the medical profession have dismissed the role of ventilation in limiting exposure to ETS in their campaign for the introduction of smoking bans, although this debate has highlighted the case that many hospitality venues do not currently use ventilation systems effectively, and that not all ventilation systems are equally effective. Ventilation systems are now being installed in hospitality venues to reduce smells that were originally masked by the tobacco smoke after the smoking ban came into force for example such as stale beer and food odours.

As a result of the negative reporting on ventilation in the debate leading up to the introduction of the ban, there is a possibility that the potential contribution from ventilation systems in managing such risks may simply be ignored. It would appear that the UK government unquestioningly accepted the argument that adequately ventilated rooms were not an alternative to a complete ban. Consequently it is now difficult for the government to offer advice to exempt building operators on how to ventilate their buildings to comply with Health and Safety requirements. Many of these buildings are government controlled and regulated.

This paper begins by explaining the regulatory framework which requires the ventilation of occupied spaces, then reviews ventilation terminology and theory for the benefit of those interested in this issue who have neither a ventilation industry background nor experience, before reviewing a number of "before and after smoking ban" studies related to this issue. Some of the studies

referred to have been presented as evidence in Government Committee reviews prior to the introduction of smoking bans.

2. Regulatory framework for ventilation in buildings

There are two primary regulations which are The Building Regulations 2000 and The Workplace (Health, Safety and Welfare) Regulations 1992 as amended by the Health and Safety (Miscellaneous Amendments) Regulations 2002 that have a bearing on the ventilation requirements for buildings in the UK. Both the Building Regulations 2000 and the Workplace (HSAW) Regulations 1992 make reference to supporting documents and guidance. This can be British or European Standards or guidance provided by relevant professional bodies, such as in this case, CIBSE, the Building Services Research and Information Association (BSRIA), or the American Society of Heating Refrigeration and Air-conditioning Engineers (ASHRAE). The Federation of European HVAC Associations (REHVA), which represents European Professional in the fields of Building Engineering Services (heating, ventilating and air-conditioning for energy efficient healthy buildings), is also a significant source of guidance in this area.

The Building Regulations 2000 apply when a new building is being constructed and to a limited extent when modifications are being carried out on an existing building. Compliance with these regulations is monitored and verified by building control bodies. Part F of Schedule 1 to the Building Regulations 2000 sets out the following requirement: Means of ventilation – *There shall be adequate means of ventilation provided for people in the building*.

Approved Document F is a commentary on the new requirements introduced in 2006, the main changes listed suggest – *a mainly performance based approach has been adopted.* Paragraph 0.21 states – *This Approved Document focuses on performance based guidance which suggests to the designer what level of ventilation should be sufficient, rather than how it should be achieved. Therefore the designer has the freedom to use whatever ventilation provisions suit a particular building, including the use of innovative products and solutions, if it can be demonstrated that they meet the performance standard recommended in this Approved Document*. The industry has and continues to deliver new products and solutions to improve indoor air quality. Paragraph 0.26 states that – *Ventilation effectiveness is a measure of how well a ventilation system works in terms of delivering the supply air to the occupants of a building. If the supply air is fully mixed with the room air before it is breathed by the occupants, the ventilation effectiveness is one.* (The calculation of decay rates relies on this assumption). *If the supply air is extracted from the room before it mixes with any room air, the ventilation effectiveness is 0. If the supply air reaches the occupant without mixing with any room air the ventilation effectiveness tends towards infinity*. This suggests that ventilation effectiveness is at least as important as air supply rate/air change rate, the normal determinant for indoor air quality. With good displacement ventilation, (air reaches occupant without mixing), effectiveness tends towards infinity and air quality tends towards being infinitely good.

Ventilation fulfils a number of different functions:

- health: respiration, odour avoidance and pollutant removal. Pollutants commonly being dealt with in buildings include nitrous oxide and carbon monoxide from combustion appliances, formaldehyde from chipboard, ETS and in some parts of the country, radon;
- cooling: removal of heat produced by internal and solar gains, both during the daytime and at night;
- comfort: provision of air movement to increase perceived cooling.

A ventilation system (whether natural, mechanical, or some combination of the two) should be able to cope with all of these situations providing draught-free ventilation with a high level of local control. Suitable systems vary according to the type of building and whether the ventilation system is being installed after or during construction. Designs can be complex, with ventilation rates varying from room to room and with the use of heat recovery devices to improve the energy performance of the building.

2.1. Ventilation and air movement in rooms (Room air diffusion)

The effectiveness of any ventilation or air conditioning system depends on the method of introduction of supply air and the removal of extract air. The condition of this supply air, the currents that are induced, the noise emitted, and the appearance and position of the openings are all factors, which directly influence the occupants' perceptions of the performance of the system. Architectural requirements will often influence terminal layout and type, but ideally the building design and structure will be designed/configured to take account of air diffusion requirements. Air diffusion is the interface between the systems and the occupants. Regardless of how well the building loads are modelled and plant and equipment selected, if the air diffusion is not well designed the system will underperform. Draughts, stagnation, poor air quality, large temperature gradients, and disturbing noise are common by-products of poor air terminal selection and positioning. It is for this reason, that the detailed specification for the ventilation system used in any "before and after" study is an essential criterion to be considered when drawing any conclusions related to the performance of the system.

2.2. Criteria for observations on "before and after" studies

The criteria set out by the authors below will be used to give an indication of the quality of the reviewed studies. Based on the experience of conducting studies "before and after" ventilation system upgrades, these are the criteria that are generally required for a "before and after" study unless measures incorporated into the design of the study mitigate against their need. The study criteria are

recorded in tabulated form under the following headings: Type of ventilation: (The type of information required here is that required to determine the ventilation effectiveness, for example if the ventilation effectiveness is 0.5, it will not perform as well as a system with an effectiveness of 2. According to Building Regulations Approved Document F (2006), ventilation efficiency can approach infinity). Air tightness of buildings: Length of measurement: Measured outdoor air quality: Weather conditions: Number of active smokers: Measured area / volume of venue (see Tables 1–4).

3. Discussion

It is interesting to note that in the published results of a number of "before and after ban" studies (Tables 1–4), the levels of ETS markers such as carbon monoxide and fine particulates are comparable with those found in well ventilated venues before the ban (Geens *et al.* 2006). Furthermore several of the authors of the papers reviewed suggest that further research is required to establish the extent to which smoke may migrate into the building from outside areas, rather than concluding that ventilation is equally effective. There is already evidence in the UK that some organisations are arbitrarily imposing exclusion zones around buildings as in the case of NHS Trusts such as the East Sussex Hospitals. The 'Smoke free NHS Policy' bans smoking from taking place outside hospital buildings and even in the hospital grounds since the 1st January 2007. These exclusion zones are not based on existing scientific evidence, exceed the requirements for example, on the separation requirements for the low level discharge of the products of combustion from heating appliances. These discharges contain amongst other things the potentially poisonous gas carbon monoxide and may be in continuous use in the winter months (Geens *et al.* 2008).

The authors of this paper intend to conduct the primary research necessary to assess the true extent and magnitude of these exposures in order to provide guidance on whether or to what extent controls are necessary as concluded by Mulcahy *et al.* 2004. Although some countries have already legislated for an outright ban, others have introduced a partial ban conditional on providing ventilation to a specified standard. The decision on which path to pursue is still to be made in many other countries, and in order to provide evidence the authors have been involved in field studies in Russia, Switzerland, the Czech Republic and Belgium. In addressing this problem, much of the research reviewed is openly antagonistic towards the use of ventilation and too readily claim that it is ineffective. This is at a time of raised awareness of concerns over exposure to ETS when effective ventilation solutions should not be ignored or simply dismissed. With the number of venues being investigated having ineffective ventilation (Carrington 2002), it is likely that this is a fundamental problem and that many venues in the United Kingdom may not be complying with existing health and safety legislation which requires "adequate ventilation".

This raises health concerns whether or not smoking is taking place. The smoking ban in Wales has allowed a number of exemptions, and it is important that such spaces are ventilated using the best techniques available in order to reduce the exposure of both user groups and staff employed in these buildings. The role of ventilation and technical guidance covering its effective use has been reviewed in a recent paper by the authors (Geens *et al.* 2007).

4. Conclusion

1. The "Findings" columns in Tables 1 to 4 summarise the conclusions of the papers under review whilst the remarks column summarises the review against the tabulated criteria. These criteria have been established as important from a review of the literature, supported directly by the findings of the authoring team of conducting field work of the same nature. The common weakness amongst the studies reviewed is that they systematically under-estimate the importance of the ventilation effectiveness, perhaps because they believe, incorrectly, that all ventilation systems are the same. It has also been observed that in most cases, the levels of monitored contaminants are reported as being at a level above zero. This is a significant observation as a major criticism of ventilation in the literature is that it cannot reduce the level of contamination to zero. Neither, it seems from a review of these papers, can a smoking ban achieve this target.

2. Rather than ignoring/dismissing ventilation as a result of these and similar studies, policymakers should be focusing on improving the standard of ventilation in all public buildings. Ventilation technology as in other fields of engineering is continually being developed and refined and therefore experience of current ventilation systems is not necessarily the best indicator of future performance.

3. This conclusion is supported by recent results presented by the authors (Geens *et al.* 2006) and further studies need to be undertaken to collect additional data before a definitive conclusion can be reached to what is a complex and multi-dimensional problem that has increasingly attracted emotional, highly biased and unscientific commentary.

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Table 1. Summary of three studies conducted between 1996 and 2004

Reference	Setting	Air tightness of building measured	Type of ventilation	Description of venues	Length of measure-ments	Measured pollutants	Measured outdoor air quality	Weather conditions recorded	Number of active smokers recorded	Measured area/volume of venue	Findings	Remarks
Ott *et al.* (1996)	A large sports tavern, 76 visits over three years (from 17th May 1992 to 15th February 1995) Various dates and times (Usually in late afternoon or evening).	Air exchange rates measured	Details of ventilation system not specified by study authors, or insufficient-ly specified to allow conclu-sions on ventilation performance to be made.	No, description of venue given by the study authors.	10 minutes to 2 hours 10 minutes	Suspended particles continuo-usly measured average taken every 2 minutes. Piezobalance Model 8510 – Monitor place in same location on a central table.	Yes, before and after each visit	No, weather conditions reported by the study authors.	Yes, every 7 minutes	Yes (521 m^3)	The research modelled indoor RSP concentra-tions from smoking by testing the model under real condi-tions in a Sports Tavern.	This paper reports reduction in ETS constituents of about 90%.
Repace (2004)	Eight hospitality venues: A casino, six bars and a pool hall. The first phases was on Friday evening, 15th November 2002, and the second on Friday evening, 24th January, 2003.	Air exchange rates calculated	Details of ventilation system not specified by study authors, or insufficient-ly specified to allow conclu-sions on ventilation performance to be made.	Yes, description and room's dimensions of each venue. All venues were located in the Wilmington metropolitan area, about 30 miles south of Philadelphia, in a county with 64% of the state's population.	30 minutes range from 15 to 45 minutes	PM 3.5, particulate polycyclic aromatic hydrocarbons (PPAH), carbon dioxide and carbon monoxide. Measurements were recorded on a Thermo Ander-son MIE pDR 1200 and a Kanomax 3511 Piezobalance, both were set to take 1- minute averaging times. The monitors were concealed in airline carry-on luggage. The monitoring package was generally unobt-rusively located along an outside wall 2 ft to 4 ft from the floor, for the bars and the pool hall areas; in the casino the package was moved about the 1000-foot perimeter of the main salon.	Yes, measured outdoor air quality.	Yes, type of weather conditions (e.g. fair and cold). Wind speed, Barometer pressure and outdoor temperatu-re were recorded.	Yes, the total number of persons present was counted at the beginning and end of the sampling period and the number of burning cigarettes being smoked was counted at the beginning, middle, and end of that period.	Yes, volume from 294 m^3 to 15,573 m^3 and area from 864 ft2 to 32,499 ft^2.	Smoke-free workplace laws eliminate the smoking hazard and provide health protection impossible to achieve through ventilation or air cleaning.	In the abstract, the author claims that smoke free workplace laws eliminate the hazard of tobacco smoke pollution, but in the conclusions this is modified to 'conside-rably reduce' such hazards. The abstract also claims that smoke free workplace laws also provide health protection impossible to achieve through ventilation or air cleaning. There is no evidence presented in this paper to support this claim.
Travers *et al.* (2004)	20 Hospitality venues: 7 bars, 6 bars/restaurants, 5 restaurants, 2 bowling alleys, a pool hall and a bingo hall 44 visits (22 visits from 11th to 23ti July and 22 visits from 9th Septem-ber to 1st Novem-ber 2003).	Air tight-ness of building not measured by study authors, or insufficient-ly specified to allow conclu-sions on air tightness of the building to be made.	Details of ventilation system not specified by study authors, or insufficient-ly specified to allow conclu-sions on ventilation performance to be made.	Yes, venues located in down-town entertainment district and suburban areas ranging from small nei-ghborough bars to large bar / restaurant chains. Smoking occurred in 14 bars and restaurants and four large recreation venues. Two bar / restau-rants allowed smoking in the bar area but not in the restaurant. In two restau-rants smoking was not allowed.	Mean time 38 minu-tes. Mea-surement time ranged from 22 to 140 minutes.	PM 2.5 respirable suspended particles were measured at 1 second intervals. TSI SidePak AM510 Personal Aerosol Monitor - Central location on a table or bar near the height at which a person breaths air. The first and last minute of the logged data was disregarded. The remaining data points were averaged to provide an average concentration of PM 2.5.	No, details of outdoor air quality not speci-fied by study authors.	No, details of weather conditions not speci-fied by study authors.	Yes, every 10 minutes	Yes, (mean 1,003 m^3)	The results indicate that a ban on smoking can substantially reduce SHS exposure.	An 84% reduction in particulates was reported. No referen-ces were made to ventilation. This paper again poses the question of whether an appropriate ventilation system would be just as effective as a ban.

Table 2. Summary of one study conducted in 2004

Reference	Setting	Date	Area	Investigation	Number of participants	Weakness of study	Strengths of study	Findings	Remarks
Sargent *et al.* (2004)	St Peter's Community hospital, Helena, Montana, USA.	Admissions from December 1997 through to November 2003.	St Peter's Community hospital serves all heart patients in Helena and the surrounding area, with a total population of 68,140. It is nearly 100 km to the next nearest hospital with cardiology services.	To determine whether there was a change in hospital admissions for acute myocardial infraction while smoking ban was in effect.	354 admissions for review with 304 meeting the criteria.	Small scale but the criteria for identifying acute myocardial infraction changed during the study.	Study done in a isolated community with a single hospital.	In the six months that the law was introduced to ban smoking in public places in an isolated community, admissions to the local hospital for acute myocardial infraction reduced compared with the same months in the years before and after the law was in effect.	This paper identifies a reduction in hospital admissions during a 6 month smoking ban but acknowledges that the small sample size is an important limitation to the study. Unfortunately the study has not identified how well the buildings were ventilated before or after the ban. It would be interesting to conduct a similar study before and after the installation of an appropriate ventilation system.

Table 3. Summary of one study conducted in 2005

Reference	Setting	Air tightness of building measured	Type of ventilation	Description of venues	Length of measurements	Measured pollutants	Measured outdoor air quality	Weather conditions recorded	Number of active smokers recorded	Measured area/volume of venue	Findings	Remarks
Mulcahy *et al.* (2005)	15 hotels in Galway City, Southern Ireland, 35 hotel employees (2–3 weeks before the ban and 4–6 weeks after the ban) – Salivary cotinine concentrations of hotel workers.	Air tightness of building not measured by study authors, or insufficiently specified to allow conclusions on air tightness of the building to be made.	Details of ventilation system not specified by study authors, or insufficiently specified to allow conclusions on ventilation performance to be made.	No, description of venue given by the study authors.	2–3 days	Screening ensured participants were from non-smokers or restricted smoking households (less than 45 minutes exposure per day to one smoker). The silver samples were collected during their shift using salivates. The samples were stored in cool boxes before being frozen within 3 hours. The samples were shipped in dry ice to London for analysis by chromatography.	No, details of outdoor air quality not specified by study authors.	Yes, mild / fine with no rain	No, the number of active smokers was not given by the study authors.	Yes, (384 to 5200 square feet)	Reduction in salivary cotinine concentrations of 69%.	This paper acknowledges limitations due to size of sample. It reports reductions similar to those found in Ventilation/no ventilation studies. The paper expresses concerns about migration of ETS from other areas. It could be argued that it would be easier to address concerns about ventilation, (operation and maintenance), than to address concerns about migration.
	19 city centre bars (Friday preceding the ban and 6 weeks after the ban) – Airborne nicotine monitoring of bars.				7–10 hours	Passive samplers contained a filter treated with sodium bisulphate were clipped to sprit drink dispensers in the bars before Friday lunch time and collected during the evening. The samples were sent to Barcelona, Spain for analysis by gas chromatography / mass spectrometry.		No, weather conditions reported by the study authors.	Yes, at the time of placing and retrieving the samples, the number of occupants and smokers were recorded. Two further counts were covertly taken.	No, the area/volume of the venue was not specified by the study authors.	There was an 83% reduction in nicotine concentrations.	

Table 4. Summary of two studies conducted in 2005

Reference	Setting	Air tightness of building measured	Type of ventilation	Description of venues	Length of measurements	Measured pollutants	Measured outdoor air quality	Weather conditions recorded	Number of active smokers recorded	Measured area/volume of venue	Findings	Remarks
Mulcahy *et al.* (2005)	9 city public houses (5 Saturday nights, 3 prior to the ban and 2 after the ban). Sampling of air quality was started at the sample time on each Saturday. All public houss were visited twice in on Saturday night.	Air tightness of building not measured by study authors, or insufficiently specified to allow conclusions on air tightness of the building to be made.	Details of ventilation system not specified by study authors, or insufficiently specified to allow conclusions on ventilation performance to be made.	Yes, public houses classified in four groups (small, medium, large and superpub).	4 minutes.	A Gt-331 particle counter was used to measure particulate matter, PM 10 PM 7, Pm 2.5 and PM 1 as a marker for Secondhand smoke (SHS) concentrations.	Yes, following the first nightly survey of the 9 public houses and before the second nightly survey at the junction of the two streets in the city centre to which vehicles had no access.	No, weather conditions reported by the study authors.	Yes, Number of occupants and smokers were recorded on each	Yes (37 m^2 to 267 m^2)	Concentrations of particulates PM 2.5 were reduced for all venues following the ban, falling by 75–96% relative to pre-ban levels. A drop in PM 10 concentrations by 47–74% relative to the pre-ban levels. PM 2.5 concentrations following the ban were approximately the same as the outside air levels.	Sampling was only carried out for four minute periods in each pub. Post ban levels are not zero. No characterisation of ventilation in use before or after ban.
Office of Tobacco Control (2005)	All Ireland Bar Study - 40 Public houses in Dublin, and county Northern Ireland. The repeat measurements were carried out on the same day of the week, and the same month, one year on. A supplementary study of 12 of the 40 public houses found a reduction in ultrafine particles. The report presents a review of he smoke-free legislation in term of compliance, public support and health benefits.	Air tightness of building not measured by study authors, or insufficiently specified to allow conclusions on air tightness of the building to be made.	Details of ventilation system not specified by study authors, or insufficiently specified to allow conclusions on ventilation performance to be made.	No, description of venue not specified by the study authors.	At Least 3 hours	Measure of particulate matter, PM 10 and Pm 2.5. The aim of the investigation is to ascertain if the legislation is to protect third parties from the exposure to and inhalation of second-hand smoke.	No, details of outdoor air quality not specified by study authors.	No, weather conditions reported by the study authors.	No, the number of active smokers was not given by the study authors.	No, the area/volume of the venue was not specified by the study authors.	From the results taken from 24 bars there has been a significant reduction in particulate levels in public houses following the introduction of the ban. There was an 87.6% reduction in the concentration of PM 2.5 and a reduction of 53% of PM 10 concentrations. Healthy smoke-free environments are part of normal work and social life.	Before and after data are presented for workplaces in Ireland. No references are made to the ventilation in use before the ban was introduced. After the smoking ban is introduced the level of contaminates does not reduce to zero.

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VĖDINIMO POVEIKIS: TYRIMAI PRIEŠ ĮVEDANT IR ĮVEDUS RŪKYMO DRAUDIMĄ

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Santrauka

Daug teisinių institucijų Europoje jau padarė ryžtingus sprendimus rūkymo viešose vietose klausimais ar dar svarsto dėl jų priėmimo. Apie alternatyvas buvo diskutuojama *Town & Country*. Būta įvairių publikacijų, susijusių su šiomis diskusijomis, pateikta mokslinių įrodymų, pavyzdžiui, Didžiosios Britanijos *Medical Journal*, *Chartered Institution of Building Services Engineers* leidiniuose. Daug išvadų siejasi su negatyviu ventiliacijos sistemų veikimo vertinimu. Apžvalga atliekama ištyrus situaciją prieš įvedant rūkymo draudimą ir jį įvedus. Siekta peržiūrėti tyrimų, susijusių su vėdinimu, išvadas ir padaryti tam tikrus sprendimus.

Reikšminiai žodžiai: vėdinimo sistemos, tabako dūmai, rūkimo draudimas, cigaretės, teisės aktai.

ВОЗДЕЙСТВИЕ ВЕНТИЛЯЦИИ: ИССЛЕДОВАНИЕ ДО И ПОСЛЕ ЗАПРЕТА НА КУРЕНИЕ

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Резюме

Многие правовые институции в Европе уже приняли решения или рассматривают возможность принятия решений, касающихся вопроса о курении в общественных местах. Дискуссия о возможных альтернативах велась в *Town & Country*. Дискуссиям на эту тему было посвящено немало публикаций, представлены научные доказательства, например, в издаваемых в Великобритании журналах *Medical Journal*, *Chartered Institution of Building Services Engineers*. Во многих выводах приводится негативная оценка действия систем вентиляции. Приводимый в статье анализ основан на исследовании ситуации до введения запрета на курение и после его введения. Предпринята попытка оценить выводы исследований, касающихся действия систем вентиляции, и предложить определенные решения.

Ключевые слова: системы вентиляции, табачный дым, запрет на курение, сигареты, правовые акты.

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