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An investigation into employee exposure to environmental tobacco smoke within designated smoking areas in the hospitality industry, with an analysis of legislative compliance of said designated smoking areas.

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Thesis submitted to the School of Physics and Clinical & Optometric Sciences

For the award of MPhil

Technological University Dublin

City Campus: Kevin Street,

Dublin

Supervisor: Professor Patrick Goodman January 2021

Abstract

Background: Occupational exposure to environmental tobacco smoke (ETS) is still occurring in the hospitality industry and the instance of non-compliant smoking areas required investigation. A designated smoking area covered by a roof where more than 50% of the perimeter of that part is surrounded by one or more walls is deemed a non-compliant smoking area. This study aimed to gather evidence of non-compliances across Dublin, determine current employee exposure whilst also measuring $PM_{2.5}$ concentrations within smoking areas as well as providing insight into possible immediate health effects of ETS exposure.

Methods: Seventy-five smoking areas (41 located in high, 27 in medium and 7 in lower socioeconomic areas) were visited from May 2019 – October 2020. $PM_{2.5}$ was recorded using a SidePak AM510 Personal Aerosol Monitor for a period of 45 minutes – 1 hour inside the smoking area. Observational forms recorded physical and contextual variables of the smoking areas including, number of smokers present, roof, perimeter boundary, size, time of day and food service. Ten healthy non-smoking volunteers (5 males, 18 – 53 years old, 5 females, 21 – 58 years old) partook in spirometry assessments pre, during and post exposure to ETS within a smoking area.

Results: Sixty per cent of smoking areas were non-compliant, with higher average $PM_{2.5}$ concentrations than compliant smoking areas (41.1 $\mu g/m^3$, 17.2 $\mu g/m^3$, ($p < .001$)). The overall distribution of venues demonstrated that non-compliance was evenly distributed across the county. Average $PM_{2.5}$ was significantly higher in smoking areas where a roof of any kind was present (36 $\mu g/m^3$, no roof = 16.3 $\mu g/m^3$, ($p < .001$)). Employees were noted working within 88% of the smoking areas visited and permanent auxiliary bars were present in 21.3% of smoking areas surveyed. When immediate effects of ETS exposure were assessed, peak flow results were suggestive of an effect between both pre exposure and during exposure ($p = 0.051$) as well as pre exposure and post exposure ($p = 0.057$).

Conclusions: Widespread non-compliance with smoke-free legislation is occurring across Dublin hospitality venues and the presence of auxiliary bars in smoking areas is placing employees at risk.

Declaration

I certify that this thesis which I now submit for examination for the award of MPhil, is entirely my own work and has not been taken from the work of others, save and to the extent that such work has been cited and acknowledged within the text of my work.

This thesis was prepared according to the regulations for graduate study by research of the Technological University Dublin and has not been submitted in whole or in part for another award in any other third level institution.

The work reported on in this thesis conforms to the principles and requirements of the TU Dublin's guidelines for ethics in research.

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Signature: Hannah Byrne Date: 08/01/2021

Candidate

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List of Abbreviations

ETS – Environmental tobacco smoke

SHS – Secondhand smoke

SES – Socioeconomic status

SE – Socioeconomic

WHO – World Health Organization

EPA – Environmental Protection Agency

HSE – Health Service Executive

USDHHS – United States Department of Health and Human Services

USDHEW – United States Department of Health, Education, and Welfare

IARC – International Agency for Research on Cancer

RSP – Respirable Suspended Particulates

U.S. EPA – United States Environmental Protection Agency

CDC – Centers for Disease Control and Prevention

COPD – Chronic obstructive pulmonary disease

AQIH – Air Quality Index for Health

OSHA - Occupational Safety & Health Administration

CO – Carbon monoxide

PM – Particulate Matter

PEF - Peak expiratory flow

PFM – Peak flow meter

HSA – Health and Safety Authority

EU – European Union

ROI – Republic of Ireland

PPM – Parts per million

PPB – Parts per billion

EHO – Environmental Health Officer

RYO – Roll your own cigarettes

TackSHS – Tackling Second-hand Tobacco Smoke and E-cigarette Emissions

WP – Work package

TFRI – Tobaccofree Research Institute

ENDS - Electronic nicotine delivery systems

ENNDS - Electronic non-nicotine delivery systems

THC – Tetrahydrocannabinol

FDA – United States Food and Drug Administration

HPRA - Health Products Regulatory Authority

HIQA - Health Information and Quality Authority

FEV1 - Forced expiratory volume in one second

FVC - Forced vital capacity

Chapter one:

Introduction to employee exposure to environmental tobacco smoke within designated smoking areas, with an analysis of legislative compliance of said designated smoking areas.

1. Introduction

Environmental tobacco smoke (ETS), also commonly referred to as second-hand smoke (SHS) is composed of the smoke present in the air that is emitted from the burning tip of a cigarette, cigar or pipe as well as the smoke exhaled by the smoker. A detailed discussion on ETS can be found in section 2.1 *Environmental Tobacco Smoke Exposure* of Chapter two. This study investigated occupational exposure to ETS in the hospitality industry particularly pubs, clubs, restaurants and cafes in Dublin, Ireland. The project aimed to observe particulates as a marker for smoke whilst also taking note of the designated smoking areas compliance in accordance to section 16 the Public Health (Tobacco) (Amendment) Act 2004 (Irish Statute Book, 2004), amending section 47 of the Principal Act (Irish Statute Book, 2002).

In 2017, the pilot study commenced, which sampled vapour phase nicotine as a marker for ETS, in smoking areas, children's playgrounds and primary school entrances in Dublin. A main conclusion of that study was that three smoking areas were discovered exposing staff to vapour phase nicotine (2.11 $\mu g/m^3$, 2.53 $\mu g/m^3$, 7.50 $\mu g/m^3$) through the provision of auxiliary bars. 50% of the smoking areas visited were also non-compliant. The pilot study confirmed that occupational exposure to ETS is still occurring in hospitality venues in Dublin through the stationing of employees at bar counters located within the venues smoking area. This contravenes the main aim of the Public Health (Tobacco)(Amendment) Act 2004 (Irish Statute Book, 2004), having regard to the World Health Organisation Framework Convention of Tobacco Control. The employees working in the aforementioned smoking areas were exposed to high levels of vapour phase nicotine presumably along with Particulate Matter of the diameter $_{2.5}$, benzene and carbon monoxide. Those employees were at a higher risk of developing respiratory illnesses, lung cancer, stroke and coronary heart disease (U.S. Department of Health and

Human Services, 2006) (Geng *et al.*, 1995) due to the placement of permanent auxiliary bars in smoking areas, a practice which is not specifically mentioned in Irish legislation, but could be deemed an extension of the licenced premises and in turn a workplace. One of the main aims of this study is to ascertain whether this problem is widespread through a larger sample size.

This study aims to further that investigation on a larger scale using $PM_{2.5}$ concentrations as a marker of ETS to form robust conclusions and recommendations to inform policy makers. $PM_{2.5}$ is particulate matter of the diameter 2.5 micrometres used to describe solid particles and liquid droplets found in the air that are capable of penetrating deep into the lungs. Smoking areas within hospitality venues across County Dublin were evaluated in order to address the concerns raised in the pilot study. The location of the study was decided based mainly on logistics. The author is based in Dublin, it is the capital city of the Republic of Ireland, and it also allowed for repeat sampling in locations used in the pilot study. The evidence of ETS was reviewed to assess the levels of exposure occurring, using $PM_{2.5}$ as a marker whilst also observing the immediate health effects of exposure through monitoring exhaled carbon monoxide, peak flow rate and spirometry of ten healthy non-smoking volunteers.

In 2012, the International Agency for Research on Cancer classified ETS as a "Group 1" carcinogen (IARC, 2012). While comprehensive smoke free laws have been in place in Ireland long before this, it is now more important than ever that those working in environments where ETS exposure is highly likely, they are protected appropriately through legislation.

A main aim of this study was to gather evidence for policy recommendations. Based on the pilot study, the level of non-compliance with the Public Health (Tobacco) Acts is expected to be high. 21.3% of venues were categorised as an extension of the licensed premises due to the presence of auxiliary bars within the designated smoking area. Employees were noted spending time within 88% of the smoking areas visited where 23% of those smoking areas fell in the upper quartile of $PM_{2.5}$ concentrations.

1.1 Study aims and objectives:

- To determine smoking areas compliance within Dublin, to assist in informing policy in respect as to whether the legislation requires amending.

- To quantify occupational exposure to ETS of workers in the hospitality industry, in particular, bar staff. The pilot study concluded that exposure was occurring and so, another aim is to form a definitive view of the situation.

- To examine the possible health effects on non-smokers post-exposure.

- This study observed whether the presence of compliant or non-compliant smoking areas are related to $PM_{2.5}$ concentrations recorded.

- A longer sampling period along with increased number of samples was proposed with the purpose of gauging the extent of the exposure and to assess whether the occurrence of occupational exposure was widespread across Dublin.

- This study aimed to build on the limitations of the pilot study by differentiating between day and night within the same venue as well as assessing variations in ETS levels from season to season.

- Gathering sufficient data regarding occupational ETS exposure and non-compliance's with the intention to initiate changes to legislation.

Chapter two: A literature review of environmental tobacco smoke, the associated health effects and current tobacco regulation.

2. A literature review of environmental tobacco smoke and exposure

In this chapter, a considerable amount of literature was reviewed to enhance the understanding of the topic and set the scene of the research. Subjects researched include environmental tobacco smoke (ETS), health implications, socio-economic status (SES) and tobacco legislation. More than 140 sources were reviewed with publication dates ranging from 1959 to 2020.

Science Direct, PubMed and Google Scholar databases were used to search for material. Alternative keywords, synonyms and acronyms were used for example: "environmental tobacco smoke", "second-hand smoke", "ETS", "SHS", "occupational exposure" and "workplace exposure" when forming search terms. Searches were carried out separately per section or chapter, which allowed for the search to remain focused.

2.1 Environmental Tobacco Smoke Exposure

The official position of the U.S. Public Health Service was declared on June 12th 1957, when then Surgeon General stated "the weight of the evidence is increasingly pointing in one direction: that excessive smoking is one of the causative factors in lung cancer" (Burney, 1959). Then, on January 11th 1964, the first report on Smoking and Health was published which established a link between smoking and numerous diseases, calling for remedial action in the U.S. (USDHEW, 1964).

U.S. Surgeon General Jesse L. Steinfeld, was the first to publish a report addressing passive smoking in 1972. He had called for a ban on smoking in public places stating non-smokers right to clean, wholesome air at the Interagency Council on Smoking and Health in 1971 (Steinfeld, 1971). This stance was then echoed in the 1972 report, where he referenced not only the discomfort of non-smoking individuals but also the varying levels of carbon monoxide they may be exposed to and the associated adverse health effects. However, at this time, "the extent of the contributions of these substances to illness in humans exposed to the concentration present in an atmosphere contaminated with tobacco smoke" was not then known (USDHEW 1972). By 1975, involuntary smoking had still not received much attention and the U.S. Surgeon General included a chapter on Involuntary Smoking detailing various substances in cigarette smoke deemed to be of particular concern to non-smokers, including carbon monoxide, nicotine, benzo(a)pyrene, acrolein, and acetaldehyde (USDHEW, 1975). Their review concluded that the effects of involuntary smoking on healthy non-smokers consisted of minor eye and throat irritation. They stated that individuals already suffering from diseases of the heart and lung were likely to see their symptoms exacerbated if exposed to smoke filled environments (USDHEW, 1975). While this report was more detailed it is clear how little was known about the health risks of involuntary smoking at this stage.

Fifteen years on from the 1964 report the Surgeon General published a comprehensive report, published in 1979, which included a detailed chapter on involuntary smoking. It stated the term "involuntary smoking" as meaning the "inhalation by the non-smoker of tobacco combustion products from smoke-filled atmospheres", involuntary in nature as inhalation occurs "as an unavoidable consequence of breathing in a smoke-filled environment", a phrase mentioned previously in the 1975 report (USDHEW, 1979).

Studies published in the 1980's began to report the relationship between cigarette smoke exposure and indoor airborne PM and gas phase nicotine (Repace and Lowrey, 1980)(Spengler and Ferris, 1985). U.S. Surgeon General C. Everett Koop, continued research in the area of the health consequences of smoking, paying particular attention to involuntary smoking. In his in-depth review, published in 1986, he stated three major conclusions: 1. Second-hand smoking is a cause of disease in healthy non-smokers including lung cancer. 2. There is an increased risk of respiratory infections, respiratory symptoms, and "slightly smaller rates of increase in lung function as the lung matures". 3. Separation of smokers and non-smokers may reduce non-smokers exposure to ETS, however it will not eliminate it completely. When reporting on lung cancer and ETS, the U.S. Surgeon General referred to data relating to the environmental levels of tobacco smoke constituents and measures of nicotine absorption in non-smokers when he suggested that non-smokers are at risk of developing lung cancer with increased exposure (USDHHS, 1986). As well as lung cancer, the U.S. Surgeon General reported on numerous studies which found a relationship between ETS and other cancers as well as cardiovascular diseases.

More recently, the U.S. Surgeon General reported on the Health Consequences of Smoking, 50 years on from the landmark 1964 report. One of the major conclusions of this report was that "exposure to second-hand tobacco smoke has been casually linked to cancer, respiratory and cardiovascular diseases, and to adverse effects on the health of infants and children" (USDHHS, 2014).

At present, it is estimated that "more than 600,000 deaths per year worldwide are caused by second-hand smoke, and about 1% of the global burden of disease worldwide with the risk factor prevalent in virtually every region of the world" (Öberg *et al.*, 2011) (WHO, 2019).

2.1.1 Sources and constituents of Environmental Tobacco Smoke

Environmental Tobacco Smoke (ETS) comes from all types of smoking including cigarettes, cigars, pipes or water pipes (commonly known as Shisha) etc. (Naeem, 2015). The constituents of ETS found in a smoke-filled environment arise from two sources: mainstream and sidestream smoke.

Mainstream smoke:

The product drawn in from the burning cigarette by the active smoker and exhaled is known as mainstream smoke (Ganapathy *et al.*, 2015) (IARC, 2012). This is the main component inhaled through active smoking.

Sidestream smoke:

The product that is then released into the air from the burning end of the cigarette, along with the exhaled mainstream smoke, is known as sidestream smoke (Ganapathy *et al.*, 2015). Sidestream smoke is that main constituent in ETS and has been shown “to have higher concentrations of toxic elements than those in mainstream smoke” (Behera, Xian and Balasubramanian, 2014). This is due to the fact that sidestream smoke is formed at a lower temperature than mainstream smoke, resulting in a higher concentration of noxious compounds per cigarette, in the gas phase (Kuusimäki, Peltonen and Vainiotalo, 2007) (Jenkin *et al.*, 1996). It is for this reason that gas phase components as well as particulates are evaluated when studying second-hand smoke exposure.

The International Agency for Research on Cancer (IARC) defined ETS as “the smoke released from the burning tip of a cigarette (or other burned tobacco product) between puffs (called sidestream smoke) and the smoke exhaled by the smoker (exhaled mainstream smoke)” (IARC, 2012).

2.1.2 <u>Components of environmental tobacco smoke</u>

In the 1979 report by the U.S. Surgeon General, they looked at the absorption by the non-smoker, stating that “many of the known substances, including nicotine, carbon monoxide and ammonia, are found in much higher concentrations in sidestream smoke than in mainstream smoke”. They concluded that while the non-smokers exposure is much less than that of the smoker, the inhaled smoke “may be qualitatively richer in certain compounds than mainstream smoke" (USDHEW, 1979). At this time, a large number of the constituents of cigarette smoke were studied, examining the ratio of sidestream smoke to mainstream smoke. Some of the results included: Carbon monoxide (10-20 mg in mainstream smoke versus 2.5mg is side stream smoke), methane (1.3 mg in mainstream smoke versus 3.1 mg in sidestream smoke), benzo(a)pyrene (20-40 mg in mainstream smoke versus 3.4 mg in sidestream smoke), nicotine (1-25 mg in mainstream smoke versus 2 mg in side stream smoke) and ammonia (80 mg in mainstream smoke versus 73 mg in sidestream smoke (USDHEW, 1979).

Researchers have been publishing information on the constituents of ETS for decades now as technology has advanced allowing more in-depth analysis to be carried out. In 2006, Repace reported ETS to contain nearly 5000 chemical compounds, which includes 172 toxic substances (Repace, 2006). While in 2013 both the Centers for Disease Control (last updated in 2018) and Tobacco Free Ireland reported ETS consisted of over 7000 chemicals, 60-70 known carcinogens and at least 250 to be disease causing chemicals (CDC, 2018) (Department of Health, 2013) (Naeem, 2015).

Both $PM_{2.5}$ and airborne nicotine have been used as markers for ETS as many studies have found a high correlation between the two (Fu *et al.*, 2013). However, as these studies exhibited, while second-hand smoke levels did not decay until some form of ventilation was introduced whereas levels dropped immediately back to background levels once the tobacco source was extinguished. It is important to note that airborne nicotine cannot be detected if there is no source of tobacco, whilst $PM_{2.5}$ may always be present at background levels emitted from a number of other sources (Fu *et al.*, 2013).

Previous studies have referred to the area in which ETS exposure is occurring indoors as microenvironments which include the home, workplace, school, car, or hospitality venues like restaurants, cafés, bars and nightclubs. Smoke free laws in Ireland have placed bans on all of these places except private homes and private cars where no children are present.

2.1.3 Particulate matter ($PM_{2.5}$)

PM2.5 is particulate matter of the diameter 2.5 micrometres used to describe solid particles and liquid droplets found in the air that are capable of penetrating deep into the lungs, as shown in figure 2.1. The World Health Organisation (WHO) describes Particulate Matter (PM) as “inhalable and respirable particles composed of sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water” affecting more people than any other pollutant (WHO, 2018). PM is separated into categories based on the size of the particles, which can range from < PM_1 to PM_{10}. The WHO also state how particles of 2.5 microns or less are capable of penetrating the lung barrier to enter the blood stream. These are referred to as respirable suspended particulates (RSP) with the maximum size considered to be 3.5 or 4 microns (Avila-Tang, Travers and Navas-Acien, 2010). “Besides molecules, radicals, atoms, and precipitations, particles with diameters larger than ~10nm and smaller than ~50 µm are collectively called total suspended particles, aerosol or PM” (Liang, 2013).

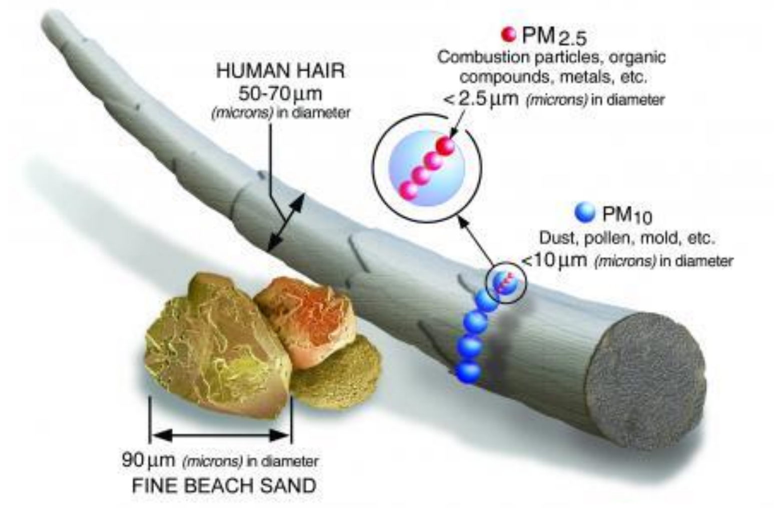


Figure 2.1: Size comparisons for PM particles (U.S. EPA, 2018)

PM is capable of depositing deep into the respiratory tract and those particles of the PM_4 fraction and smaller have been associated with serious health problems. Exposure has been studied through epidemiological data suggesting the capability of increasing mortality and morbidity of cardiopulmonary diseases like pre-existing chronic obstructive pulmonary disease (COPD), cardiovascular diseases and exacerbation of asthma (Mueller *et al.*, 2011) (Yeatts *et al.*, 2007). $PM_{2.5}$ in particular has been associated with lung cancer mortality (Pope III *et al.*, 2002). In 2013, the WHO's International Agency for Research on Cancer (IARC) classified $PM_{2.5}$ as a cause of lung cancer (WHO, 2018b). It is for this reason that this study will use $PM_{2.5}$ as a marker of tobacco smoke exposure and consider the health effects that can accompany this exposure.

A study carried out in 2014 looked at outdoor tobacco smoke exposure and its relation to the distance from the smoking source. They found "$PM_{2.5}$ levels were significantly higher with smoking than without smoking", an expected outcome in an outdoor area. More interestingly, the outdoor tobacco smoke was detectable (2.6 $\mu g/m^3$) even at 9 metres away from the smoking source of only 1 cigarette (Hwang and Lee, 2014).

$PM_{2.5}$ and nicotine in the air have been described as reliable indicators of ETS exposure. This was outlined in studies from the 1980's where the authors concluded that tobacco smoke was "a potent source of fine indoor airborne PM (Repace and Lowrey, 1980) (Spengler and Ferris, 1985), whilst nicotine in its gaseous phase was a sensitive and specific marker of exposure" Hammond and Leaderer, 1987, Schlotzhauer and Chortyk, 1983, Rickert, Robinson and Collishaw, 1984. Studies by Apelberg *et al.*, 2013 and Avila-Tang *et al.*, 2010 have described the correlation between the two. Apelberg *et al.* report that while nicotine measurements in the air are specific to tobacco smoke and $PM_{2.5}$ is not, $PM_{2.5}$ can be measured continuously, "allowing for assessment of exposure and its variation over time" (Apelberg *et al.*, 2013). They go on to state that, generally in areas where there is consistent smoking, correlation between nicotine and $PM_{2.5}$ is good when using a common sampling period, "with an increase in nicotine concentration of 1 µg/m^3 corresponding to an average increase of 10 µg/m^3 of $PM_{2.5}$" (Apelberg *et al.*, 2013), (Avila-Tang, Travers and Navas-Acien, 2010).

Table 2.1: $PM_{2.5}$ health categories (Environmental Protection Authority Victoria, 2019)

Air quality category	$PM_{2.5}$ µg/m^3 averaged over 1 hour	$PM_{2.5}$ µg/m^3 averaged over 24 hours
Good	Less than 27	Less than 8
Moderate	27–62	8–25
Poor	62–97	25–40
Very poor	97–370	40–177
Hazardous	More than 370	More than 177

Across the world, environmental agencies monitor air quality in their respected regions. Table 2.1 is from the Australian Environmental Protection Agency, which shows the levels of $PM_{2.5}$ and their designated health categories. When a value of 62 µg/m^3 in one hour is detected, a "poor" air quality category is assigned. When they detect a 24-hour rolling average of 25 µg/m^3 or higher, a cautionary health warning is displayed on their website.

Table 2.2: How the EPA calculate the Air Quality Index (EPA, 2019b)

Four bands of air quality:	Index (1-10):	Ozone Running 8-hour mean (µg/m³)	Nitrogen dioxide 1-hour mean (µg/m³)	Sulphur dioxide 1-hour mean (µg/m³)	$PM_{2.5}$ particles Running 24-hour mean (µg/m³)	PM_{10} particles Running 24-hour mean (µg/m³)
		Five air pollutants which can harm your health:				
Good air quality	1	0-33	0-67	0-29	0-11	0-16
	2	34-65	68-134	30-59	12-23	17-33
	3	67-100	135-200	60-89	24-35	34-50
Fair air quality	4	101-120	201-267	90-119	36-41	51-58
	5	121-140	268-334	120-149	42-47	59-66
	6	141-160	335-400	150-179	48-53	67-75
Poor air quality	7	161-187	401-467	180-236	54-58	76-83
	8	188-213	468-534	237-295	59-64	84-91
	9	214-240	535-600	296-354	65-70	92-100
Very Poor air quality	10	241 or more	601 or more	355 or more	71 or more	101 or more

In Ireland, the EPA monitors $PM_{2.5}$ as part of their air pollution monitoring across the country displaying real time on their Air Quality Index for Health (AQIH). Table 2.2 shows how the EPA here in Ireland calculate the air quality based on the measurements of five air pollutants, one of which is $PM_{2.5}$.

The Ambient Air Quality and Cleaner Air for Europe (CAFÉ) Directive 2008/50/EC, sets out the legal limit values for specific air pollutants including $PM_{2.5}$. The averaging period for $PM_{2.5}$ is one calendar year, limit value of 20µg/m^3, for the protection of human health (limit value attainment date 1st January 2020) (European Commission, 2008). However, the World Health Organisation AQ guideline limits for $PM_{2.5}$ are much lower, 10µg/m^3 annual mean and 25µg/m^3 24-hour mean (WHO, 2005). In 2017, all monitoring stations in Ireland, shown on the AQIH, had exceedances of the daily WHO air quality guideline value for $Pm_{2.5}$ (Fitzpatrick, 2019).

It is also important to note that there are other major sources of fine particles in background air from transport, construction, fuel burning, domestic wood burning stoves, barbeques as well as commercial and domestically used gas heaters. In a city like Dublin, these human-made particulates are most common however, particulate matter can occur from natural sources such as, ash, sea-spray and pollen. These all contribute to the ambient background air quality and should be accounted for during measurements of fine particulates to assess the ambient levels.

2.2 Health effects of environmental tobacco smoke

Publications warning of the implications of ETS exposure include reports of the U.S. Surgeon General (mentioned previously), The National Academy of Sciences, the IARC, the EPA and the Occupational Safety & Health Administration (OSHA). Their reports and many more all concluded that non-smoker ETS exposure can cause "fatal heart disease, lung (increased risk of development by 20-30%), breast, and nasal sinus cancer, asthma induction and aggravation, middle ear infection, sudden infant death syndrome, and respiratory impairment, as well as irritation of the mucous membranes of the eyes, nose, and throat" (Repace, 2006) (Carreras *et al.*, 2020). In her 2010 report, the U.S. Surgeon General revealed that approximately 3,000 non-smokers die annually from lung cancer, 34,000 from heart disease with those exposed in the home or at work increasing their risk of developing it by 25-30%. The risk of stroke is increased by 20-30% causing 8,000 deaths by stroke each year (USDHHS, 2010) (Wallace, 2007) as a result of ETS exposure (USDHHS, 2010). Other than the cancer and heart diseases mentioned previously, ETS exposure has been reported to lead to eye irritation in 69% of cases, headaches in 33% of cases, nasal symptoms in 33% of cases and cough and allergic reactions in 33% of cases (Naeem, 2015).

2.2.1 Exhaled Carbon Monoxide

Carbon monoxide (CO), is a colourless odourless gas, generally produced from the incomplete combustion of fossil fuels. However, CO is also present in the gas phase of tobacco smoke. It is a toxic agent formed through incomplete combustion of the tobacco (Goniewicz *et al.*, 2009). Carbon monoxide is inhaled directly by the smoker in the mainstream smoke and the CO inhaled by the active smoker can range from 5 to 22 mg/cigarette, while levels in sidestream smoke, emitted into the atmosphere, ranging from 9 to 35 mg/cigarette (Czogala and Goniewicz, 2005) (Calafat *et al.*, 2004) (Goniewicz *et al.*, 2009). Smokers experience adverse health effects through the binding of CO to haemoglobin in the blood, forming carboxyhaemoglobin. CO takes the place of oxygen on the haemoglobin, and is why carboxyhaemoglobin is a biomarker of CO exposure in humans. As a result, reduced levels of oxygen reach the body's organs and muscles (National Institute of Public Health and the Environment, 2018) posing the question; does passive smoking result in involuntary CO poisoning due to low level exposure?

Exhaled CO tests are often used to assess an individual's smoking status in smoking cessation clinics (Hung *et al.*, 2006). The non-invasive diagnostic test which measures the concentration of carbon monoxide in expired breath "bears a close relationship to blood carboxyhaemoglobin concentration" allowing for the detection of CO exposure (Cunnington and Hormbrey, 2002). Various studies have reported a direct relationship between blood carboxyhaemoglobin concentration and an individual's smoking status (Deveci *et al.*, 2004).

2.2.2 Peak expiratory flow

Peak expiratory flow (PEF) rate is a pulmonary function test carried out by a handheld peak flow meter (PFM) which measures the air flowing out of the lungs. PFM's are often used in asthma patients to measure the functional status of the lungs, but they are also used to assess changes occurring in the lung function from treatment or environmental exposures (Lebowitz, 1991). PEF is the maximum flow exhaled from the lungs for at least 10 milliseconds, showing the volume and rate of air that can be forced out of the lungs after a full lung inhalation expressed in litres per minute (Leiner *et al.*, 1963). "Normal" peak flow varies according to the person's age, height and sex but adults range between 400-700 litres per minute.

2.2.3 Occupational exposure to ETS

The burden of disease on workers exposed to ETS has been well documented as countries around the world advocated for workplace smoking bans, including an extensive report by an independent scientific working group commissioned by the Health and Safety Authority (HSA) and the Office of Tobacco Control in Ireland (Allwright *et al.*, 2002). While these bans were enacted, with Ireland leading the way in 2004 following advice from the aforementioned report, many policy makers encountered the same limitations. Exemptions from the indoor smoking ban to protect the rights of the individual residing there were favoured over the protection of employees. These include the prison service, hospices, psychiatric hospitals, hotel rooms and nursing homes for example. Prison workplace exposure has been investigated both within the Irish prison system and abroad (Ritter *et al.*, 2012) (Jayes *et al.*, 2016) (Semple *et al.*, 2017) . Demou *et al.* and Semple *et al.* also documented the effects of smokefree policies in prisons across Scotland which resulted in significant reductions in ETS exposure, an extremely positive result for employees and prisoners (Demou *et al.*, 2020) (Semple *et al.*, 2020). In Ireland, ETS exposure in nursing homes and psychiatric hospitals reported levels 45% higher than pre smoking ban levels recorded in Dublin pubs (McCaffrey *et al.*, 2012).

There also cannot be an assumption that all hospitality employees are "healthy" either, when Ireland has the 4th highest prevalence of asthma in the world (Nolan and Murphy, 2020). A respiratory illness which would be effected when exposed to second hand smoke, a common trigger (CDC, 2020). One study concluded that short term exposure of females with asthma to ETS resulted in significant effects on spirometry measurements (Keogan *et al.*, 2020). Regardless of the health status of employees, workplace exposure should not occur and must be addressed.

The pilot study concluded that occupational exposure was occurring in the hospitality industry with the presence of auxiliary bars within designated smoking areas, an extension of the licenced premises. A main aim of this study is to see if two to three years later, this is still happening and to what extent. Due to the small sample size completed in the pilot study, further investigation was necessary in order to gather sufficient evidence to present to the Environmental Health Association of Ireland.

2.3 Socio-economic status

In the pilot study, socio-economic status (SES) was discussed in detail as this categorisation formed an integral part of the European study. A range of variables, which include income or financial status, occupation and education, generally predicts a person's SES. While these variables may be interrelated, it has been suggested that individual and societal forces linked with health is reflected differently in each (Byrne, 2018). In 1992 Winkleby, *et al.*, discussed these factors. Income or financial status reflects medical care, housing and disposable income. Occupational status reflects prestige and work exposures. While education stipulates an individual's skills requisite for obtaining positive social, economic and psychological resources (Winkleby *et al.*, 1992). In this study, data from the 2016 census was used via the Pobal map to check venue location SES. The Irish census measures SES by age dependency ratio, lone parent ratio, level of education received, proportion of local authority rented housing and unemployment rates of both males and females (Pobal, 2016).

In 2005, Laaksonen *et al.*, discussed the links between a population groups SES and their smoking prevalence. It could be assumed that education level is associated with occupational status, which in turn reflects the knowledge and skills considered essential for making health behaviour choices concerning smoking. However, population groups that fall into the lower SE groupings consistently rank highest in smoking prevalence regardless of limited incomes associated with said groups: "income and other measures of material well-being are inversely associated with smoking" (Laaksonen *et al.*, 2005).

The HSE smoking prevalence tracker has recorded cigarette smoking prevalence by SE group available from 2013. The social class categorisation used by the HSE is sourced from AIMRO Standard Guide for Social Class and separates into seven categories (A, B, C1, C2, D, E, F). The tracker has consistently reported prevalence as being highest among the lower SE groups C2 and DE (group D and E are combined in reports). These groups are described as: C2 = "All skilled manual workers and those manual workers with responsibility for other people", D = "All semi-skilled and unskilled manual workers", E = "All those entirely dependent on the state long-term; those unemployed for period exceeding 6 months" (HSE, 2018c). Between 2013 and 2018, while the percentages fluctuate, they have remained highest in the C2 and DE groups (see appendix 7.1 for the breakdown of smoking per SE group).

2.4 Tobacco legislation

Around the world, tobacco legislation has become an important step in improving population health. However, comprehensive smoke free laws have been successfully introduced in few countries. In Ireland, regulation of tobacco began with control of tobacco advertising, sponsorship and sales in 1978. The biggest success to date, however, was the outright ban on smoking in the workplace and all indoor public places, enacted by the Public Health (Tobacco) (Amendment) Act of 2004. The HSE Tobacco Free Ireland Programme report published in 2013 set the goal of a smoke free Ireland (<5% prevalence) (Department of Health, 2013). Assuming the current trend (reported in Healthy Ireland surveys) continues <5% prevalence may not be reached by 2025 at the current rate it is dropping. From 2015 to 2019 smoking prevalence has dropped gradually (23%, 23%, 22%, 20%, 17% respectively) (Department of Health and Ipsos MRBI, 2019).

Table 2.3: Tobacco control legislation in Ireland currently includes:

Year	Legislation and main regulations enacted	
2002	Public Health (Tobacco) Act, 2002	Ban on sale of tobacco products to those under 18 years of age
2004	Public Health (Tobacco) (Amendment) Act 2004	Workplace smoking ban.
2007	Public Health (Tobacco) (Amendment) Act 2004 (Commencement) Order 2007	Ban on packets containing less than 20 cigarettes
	Public Health (Tobacco) (Amendment) Act 2004 (Commencement) Order 2007	Ban on the sale of confectionaries that resemble cigarettes
2009	Public Health (Tobacco) (Amendment) Act 2004 (Commencement) Order 2008	Ban on the point of sale display and advertising of tobacco products
	Public Health (Tobacco) (Amendment) Act 2004 (Commencement) Order 2008	Requirement for all tobacco products to be stored within a closed container which can only be accessed by the retailer
	Public Health (Tobacco) (Registration) Regulations 2009	Requirement for all retailers who wish to sell tobacco products to register with the National Tobacco Control Office
	Public Health (Tobacco) (Self Service Vending Machines) Regulations 2009	Prohibition on self-service vending machines except in licensed premises or in registered clubs.
2011	Public Health (Tobacco) (General and Combined Warnings) Regulations 2011	Health warnings in written and visual form on cigarette packets.
2016	Protection of Children's Health (Tobacco Smoke in Mechanically Propelled Vehicles) Act 2014	Ban on smoking in mechanically operated vehicles where children are present
2017	Public Health (Standardised Packaging of Tobacco) Regulations 2017.	Ban on promotional packaging – standardised packaging of tobacco
2018	European Union (Manufacture, Presentation and Sale of Tobacco and Related Products) (Amendment) (No. 2) Regulations 2018	Set limitations on liquid nicotine refills of 10ml and disposable e-cigarettes or single use cartridges cannot exceed a volume of 2ml.
2019	Public Health (Tobacco Products and Nicotine Inhaling Products) Bill	Plans to ban on sale of e-cigs to under 18s/ ban on tobacco vending machines and at locations aimed at children/ mobile units

Another significant tobacco control measure introduced has been the increasing taxation of tobacco. In 2016, a report published by EUROSTAT reported that the price of alcohol and tobacco were highest in Ireland and the United Kingdom, 175% and 162% of the EU average respectively, due to higher taxation on these goods (Bourgeais and Gasic, 2017). The cheapest being in Poland (68%), Hungary (67%) and Bulgaria (56%) (Bourgeais and Gasic, 2017). Since 2016, the price of 20 cigarettes in Ireland has continued to rise, from €10.50 to €14 in the 2021 budget. While in the UK, the price has risen from £9.40 in 2016 to £10.80 in 2019 with an unknown price for 2021 post BREXIT.

2.4.1 Comprehensive smoke-free laws: smoking bans

As mentioned in the previous section, a workplace ban was introduced in 2004. The Public Health (Tobacco) Act 2002 was amended, establishing a comprehensive workplace smoking ban, a first in the world. An abundance of studies have reported the health benefits of smoke-free laws, providing further evidence in support of the conclusions of review papers published in 2009 (Goodman *et al.*, 2009), 2010 (Callinan *et al.*, 2010), and 2016 (Frazer *et al.*, 2016). Since the first smoking ban was introduced in the Republic of Ireland in 2004, many countries followed suit. Bans were followed by further regulation of tobacco products. These conclusions all stated that introducing comprehensive smoke-free laws do lead to reductions in exposure, with hospitality workers reaping the greatest benefits when compared to the general population (Callinan *et al.*, 2010).

As of 2020, 17 European Union countries have comprehensive smoke-free laws including: Rep. of Ireland, the UK, Greece, Bulgaria, Malta, Spain and Hungary. Their laws include a complete smoking ban in enclosed public spaces, workplaces and on public transport (European Commission, 2019). The Commission states that “the health effects of smoke-free legislation are immediate” including reduced incidence of heart attacks and improved respiratory health (European Commission, 2019).

Around the world, many other countries have also implemented smoke-free laws, including: Norway, Italy, United Kingdom, Spain and the Czech Republic for example (Smoke Free Partnership, 2015). While the United States does not impose a federal smoking ban, individual states have enacted comprehensive laws. The Smoke Free Air Act 2002 bans smoking in the workplace, hospital entrances, public transport, city parks, beaches, zoos, outdoor seating areas of restaurants, playgrounds and pedestrian plazas in New York City with exemptions for tobacco bars, members clubs and promotional events for tobacco products (Department of State Division of Administrative Rules, 2003). California was even earlier; in 1995 they enacted a state-wide smoking ban in all enclosed workplaces before including bars and restaurants from 1998 (Friedman, 1995).

2.4.2 Review of health benefits associated with comprehensive smoke-free laws

While there is inconsistent evidence as to the effect of smoking bans on smoking prevalence globally as reported in the Cochrane review, one cannot dismiss the evidence that smoke free policies in workplaces are associated with tobacco cessation and decreases in prevalence (Hopkins *et al.*, 2010). In a study of 21 locations, 13 did not see a change in smoking prevalence, however, in both Washington and the Republic of Ireland, the level of smoking immediately declined (immediate decrease of 1.18% in ROI) after the introduction of smoke-free laws (Bajoga *et al.*, 2011). While the ROI saw an immediate decline after the ban, as one of the only countries to collect monthly data, smoking prevalence had been declining at a statistically significant rate prior to the ban, and ultimately, no change in the trend occurred (Bajoga *et al.*, 2011). This highlights the overarching struggle public health officials face when it comes to tobacco legislation and smoking cessation; comprehensive tobacco legislation must be accompanied with high tobacco taxation, sponsorship and advertising prohibitions, education and health initiatives for example. These prohibitions not only remove the marketing strategies used by tobacco companies, but also reduce the rate of young people both exposed to and enticed to start smoking.

Studies have repeatedly reported improvements in worker health, most notably, respiratory and cardiovascular health (Semple *et al.*, 2007) (Goodman *et al.*, 2009) (Issa *et al.*, 2011). An evaluation of the smoking ban in 585 hospitality venues in Sao Paulo, Brazil reported reductions in exhaled carbon monoxide levels from a total of 627 employees. Their results were reductions from 15.78ppm to 11.50ppm (27% reduction) in smoking employees and 6.88ppm to 3.50ppm (45% reduction) in non-smoking employees (Issa *et al.*, 2011). In Ireland, Goodman *et al.* found a 79% reduction in exhaled carbon monoxide in never smokers sampled pre and post smoking ban.

Issa *et al.* did not record $PM_{2.5}$ in their study but rather CO, which decreased by 70%, and so it cannot be compared to the results of Goodman *et al.* However, a smaller study of 16 venues in Sao Paulo, which measured airborne nicotine as a marker for ETS reported 72% reduction in nicotine within venues sampled before and after the Brazilian smoking ban (Andreis *et al.*, 2011).

Goodman *et al.* assessment of employee health and associated benefits of a smoking ban was investigated in 42 hospitality venues in Dublin before the smoking ban was introduced and again one year later after introduction. This study recorded $PM_{2.5}$ and PM_{10} concentrations in all venues with a subgroup of 26 venues also recording benzene. Pulmonary function, exhaled carbon monoxide and salivary cotinine levels were recorded for 81 employees as part of the health assessment. The results of this study found $PM_{2.5}$ concentrations reduced by 83% from an average of 35.5µg/m^3 to 5.85µg/m^3 indoors, as well as an 80.2% reduction in benzene concentrations from 18.8ppm to 3.7ppm. When they compared results of their health assessments, there was also an 81% reduction in salivary cotinine. They also reported "statistically significant improvements in measured pulmonary function tests and significant reductions in self-reported symptoms and exposure levels in non-smoking barmen volunteers after the ban" (Goodman *et al.*, 2007).

Although we cannot directly compare results from Dublin with Sao Paulo due to the different methods, there is a notable difference in the level of reduction in exhaled carbon monoxide: 45% reduction in Brazil versus a 79% reduction in Irish bar staff. When Semple et al. examined bar worker health before and after the implementation of Scottish smoke-free legislation they too reported large reductions in workplace exposure to SHS as well as 89% reduction in salivary cotinine levels in non-smokers (Semple *et al.*, 2007).

A study of the Italian smoking ban also revealed significant decreases in $PM_{2.5}$ from 119.3 $\mu g/m^3$ to 38.2 $\mu g/m^3$ 3 months post ban, a 68% reduction (Valente *et al.*, 2007). While urinary cotinine levels reduced by 73%, in comparison to the 81% reduction in salivary cotinine levels of Irish bar staff. The Cyprus smoking ban resulted in a substantial reduction of 98% in $PM_{2.5}$ recorded in 35 venues, from 161 $\mu g/m^3$ to 3 $\mu g/m^3$ (Christophi *et al.*, 2013).

In May 2005, Sweden banned smoking in bars and restaurants. Seventy-one people took part in a pre and post ban study by Larsson *et al.* who measured exposure to ETS, smoking habits, spirometry, respiratory and sensory symptoms as well as attitudes towards the ban. Fourteen volunteers were daily smokers, 37 worked in gambling venues while 54 in bars/ restaurants. The 12-month follow-up results reported that respiratory and sensory symptoms had halved in the non-smokers. ETS exposure dropped from 87% to 22%. This study, however, did not find notable changes in lung function (Larsson *et al.*, 2008). As of July 1st 2019, Sweden has since taken the next step in protecting public and occupational health by banning smoking in outdoor areas like train stations, airport entrances, children's playgrounds and outdoor areas of hospitality venues (The Swedish Parliment, 2019).

In March 2006, Scotland implemented smoke-free legislation in all confined public places e.g. workplaces, restaurants and bars. A study by Menzies *et al.* measured "respiratory and sensory symptoms, spirometry measurements, serum cotinine levels, peripheral inflammatory cell count, asthma quality-of-life scores, and exhaled nitric oxide levels were evaluated before and after introduction of the smoking ban". They found a rapid (within 2 months) improvement in the health of non-smoking employees including: reduction in respiratory symptoms, sensory symptoms and inflammation or swelling of airways as well as improvements in lung function and overall quality of life for those with asthma (Menzies *et al.*, 2006).

Rapid improvement of respiratory health was also noted in a 1998 study of bartenders in San Francisco, California, after introduction of smoke-free policies. Both self-reported respiratory and sensory irritation symptoms were resolved as well as observed improvements in spirometry tests where complete cessation of workplace ETS exposure occurred (FVC (0.287 L; 95% CI, 0.088-0.486; 6.8% change) and mean FEV1 (0.142 L; 95% CI, 0.020-0.264 L; 4.5% change)) (Eisner, Smith and Blanc, 1998).

2.4.3 The designated smoking area in Irish legislation

The Public Health (Tobacco) (Amendment) Act 2004 set out the specifics for designated smoking areas under Irish law. Section 16 of the 2004 Act amends section 47 of the Principal Act. In part 4 paragraphs *(c)* and *(d)* apply to premises in which this study is centred on:

"(c) subject to paragraph (d), a place or premises, or a part of a place or premises, that is wholly uncovered by any roof, whether fixed or movable,

(d) an outdoor part of a place or premises covered by a fixed or movable roof, provided that not more than 50 per cent of the perimeter of that part is surrounded by one or more

walls or similar structures (inclusive of windows, doors, gates or other means of access to or egress from that part)" (Irish Statute Book, 2004).

Due to the wording of the legislation, it became apparent that Environmental Health Officers (EHOs) and the public were interpreting it differently. This lead to a number of high court cases, which lead to the clarification of the HSEs position. These are all included in the Section 47 Letter used by EHOs to advise proprietors on the interpretation of the legislation. However, the letter clearly states that "the decision on whether a particular structure is exempt is ultimately a matter for the courts" and that "the Public Health Tobacco Acts have no provision for approval of exempted areas and make no reference to smoking areas per se. Thus neither the HSE nor an authorised officer have the legal authority to give a formal approval or exemption for such an area".

The results of these high court cases were outlined in a letter discussing the legislation and the decisions of the courts. The first judgement came about in the Brookshore case (High Court record number: 2010 85 SS) when Justice Charleton found that "the material that makes up a roof is irrelevant; a roof is a roof", clarifying that a "roof" includes a canvas awning. A second case expanded on the topic of the roof by saying "almost the entire area is roofed either by the roof of the pagoda structure or by the overhanging gutters/ soffits of the original premises".

With regard to paragraph *(d)* another high court case provided clarification about the "perimeter". The court said that a "wall does not have to be made of bricks or stone, but that any enclosing structure will be sufficient to constitute a 'wall or similar structure'". Similarly, the St. Johnston case (High Court record number: 1266 2012) demonstrated that a "a wooden surround not more than one metre-high or even seating along a relevant perimeter can constitute a "wall or similar structure". When it comes to roof structures and the surrounding walls, it is at the discretion of the courts to decide if the area is deemed indoors with respect to the distance between the perimeter and the roof. However, it is important to note that the section 47 letter states that if enforcement proceedings do not go ahead it does not necessarily mean that the structure has been deemed exempt or thought to be an approved structure.

2.4.4 Smoking prevalence

Smoking prevalence records in Ireland are not all directly comparable due to different survey models used throughout the years. The 2007 SLAN Report reported that smoking prevalence had decreased, mainly between the years 1998-2002 (33% and 27% respectively), stating that no further reduction was seen between 2002 and 2007 (29%) (Morgan *et al.*, 2008). As part of the TackSHS project, face-to-face surveys on smoking were conducted across 12 European countries (Bulgaria, England, France, Germany, Greece, Ireland, Italy, Latvia, Poland, Portugal, Romania and Spain). The results represented 80% of the EU population and found that 25.9% of those 15 and older were current smokers (31% among men and 21.2% among women) (Gallus *et al.*, 2020).

Since 2002, the HSE Smoking Prevalence in Ireland Tracker Survey (https://www.hse.ie/eng/about/who/tobaccocontrol/research/) has reported on population smoking prevalence, e-cigarette use (since 2015) and roll your own cigarettes (RYO). The survey, carried out by the Office of Tobacco Control, was then passed onto the HSE when the office dissolved in 2010. The tracker involves a nationally representative poll of 1000 people 15 years and over who are contacted by phone quarterly (Hickey and Evans, 2014). From 2005 to 2018, the HSE tracker reported a decrease in prevalence by 20.6%; a reduction of 1.9% per year relative to the previous year" (HSE, 2018c). In 2003, prior to the smoking ban the tracker reported prevalence at 28.28%, then after the ban in March 2004 prevalence dropped to 27.97% in September 2004 and 27.13% in December 2005. The tracker reported the biggest drop between December 2008 and December 2009 from 27.16% to 24.59% (Hickey and Evans, 2014). However, due to a smaller sample size, "it is a less definitive measure of smoking prevalence than the Healthy Ireland Survey" (HSE, 2018c). The Healthy Ireland Survey, started in 2015, is the source used for national and international reporting (Department of Health and Ipsos MRBI, 2017).

Table 2.4: Smoking prevalence in Ireland.

HSE Smoking Prevalence Tracker:				**Healthy Ireland Survey:**			
Year	**% Prevalence**	**E-cig use**	**RYO**	**% Prevalence**	**E-cig use**	**RYO**	**SHS daily exposure**
2014	19.5%	--	24.6%	--	--	--	--
2015	19.2%	4.7%	26.9%	23%	--	5%	--
2016	18.7%	4.7%	28.5%	23%	3%	--	18%
2017	17.5%	5.7%	29.2%	22%	4%	--	16%
2018	18.1%	5.9%	28.4%	20%	4%	--	--
2019	17.1%	6.3%	30.5%	17%	5%	--	--
2020	15.4%	5.8%	29.6%	Not published			

Unfortunately, data reported has not been consistent as can be seen in table 2.4. From 2015 - 2019 prevalence has been reported by Healthy Ireland as 23%, 23%, 22%, 20% and 17% respectively.

2.5 Tobacco Free Ireland Programme

As part of the Healthy Ireland initiative, the Tobacco Free programme was set up in 2016. The main aims of the programme are to "take responsibility for and systematically drive policy priorities in the area of tobacco control across the HSE" and ultimately, "mobilise the health services to improve health and wellbeing and play its part in the achievement of a reduction in smoking prevalence to less than 5% of the population by 2025" (HSE, 2018a). One of the objectives is to "monitor, build and maintain compliance with tobacco legislation", which is a responsibility of EHOs and their Tobacco Officer.

The deadline for achieving < 5% smoking prevalence is fast approaching and it is difficult to see how this will be done when prevalence was 17% in 2019 having only fallen 6% in the last 4 years. While the tax has continuously risen, it does not appear to be significant enough to deter smokers. However, e-cigarette usage has risen as well as roll your own. It could be assumed that the price of cigarettes (€14) plus the current economic state is causing more people to move to roll your own or e-cigarettes, with 10% of e-cigarette users current smokers, 13% ex-smokers and 1% non-smokers (Health Service Executive, 2019a).

2.6 Tackling Second-hand Tobacco Smoke and E-cigarette Emissions: A European Union Horizon 2020 Project.

In 2017, as part of the authors undergraduate dissertation, fieldwork was undertaken in conjunction with the Tobaccofree Research Institute as the Irish partner in the European study. The results of which are presented for background literature on the pilot study being relevant to the present study. TackSHS was a research project funded by the European Union's Horizon 2020 Research and Innovation Programme.

The project consisted of 11 work packages (WP) conducted across 12 European countries (Bulgaria, France, Germany, Greece, Ireland, Italy, Latvia, Poland, Portugal, Romania, Scotland and Spain). The objective was to "elucidate the comprehensive impact that SHS and e-cigarettes emissions have on the respiratory health of the European population and how health impacts vary according to socio-economic parameters with particular emphasis on specific vulnerable groups" (Institut Catala D'oncologia, 2015) (TackSHS, 2019a).

The Tobaccofree Research Institute were involved in WP 2 and 5 of the TackSHS project. Work package 2, titled: "the environmental assessment of SHS exposure in private settings and outdoor settings according to country-specific smoke-free policies and socioeconomic characteristics", focused on non-regulated settings including private settings, children's playgrounds, entrances to primary schools and outdoor terraces of hospitality venues. Vapour phase nicotine was measured at each venue to measure the possible exposure within the environment.

2.6.1 Identifying venues

There were 60 samples required from each participating country, spread evenly between children's playgrounds, primary school entrances and hospitality terraces. With assistance from TFRI, following the TackSHS protocol, venues were chosen using the Pobal HP Deprivation Indices, layer list: 2011 – by small area, accessed through the online Pobal Maps Portal. As this fieldwork required the researcher to enter children's playgrounds, local authorities were notified with the assistance of a Principal EHO via a letter. Similarly, a letter signed by both TFRI and the lead investigator from WP2 was included in correspondence with all primary schools along with Garda Vetting clearance. Due to the nature of the work, hospitality venues were not informed to ensure behaviour of staff and clientele was authentic.

2.6.2 Instrumentation and observational forms

Vapour phase nicotine was measured using an active sampling method. The samplers consisted of 37-mm diameter plastic cassette containing a filter treated with sodium bisulphate to allow for the specific collection of nicotine. An SKC Sidekick Deluxe air pump was used to perform active sampling. The pump was set to a specific flow rate of 2 -3 1/min and measured for a 30-minute period (Henderson *et al.*, 2020b). Observational forms were completed for each venue throughout the sample period to record various possible variables for each venue. Irish samples were then returned to the Public Health Agency of Barcelona where they were analysed using the gas chromatography/ mass spectrometry method.

2.6.3 *Sampling results*

Overall, children's playgrounds had the lowest nicotine concentrations with 19 of 20 below the limit of detection (<0.06 µg/m^3). Results from observations showed evidence of smoking inside 55% of playgrounds and just outside 95%. There was also evidence of smoking at 60% of primary school entrances. Active smoking was recorded at 60% of schools located in lower SE areas while at only one school in a higher SE area. However, the nicotine results did not reflect this. As expected, smoking areas had the highest nicotine concentrations with expected differences between those located in higher and lower SE areas (average of 2.99 µg/m^3 and 7.08 µg/m^3 respectively). Additionally, three of the venues contravened the Public Health (Tobacco) (Amendment) Act 2004 as they had functioning auxiliary bars located within the area, an extension of the licenced premises, exposing employees full time to second-hand smoke.

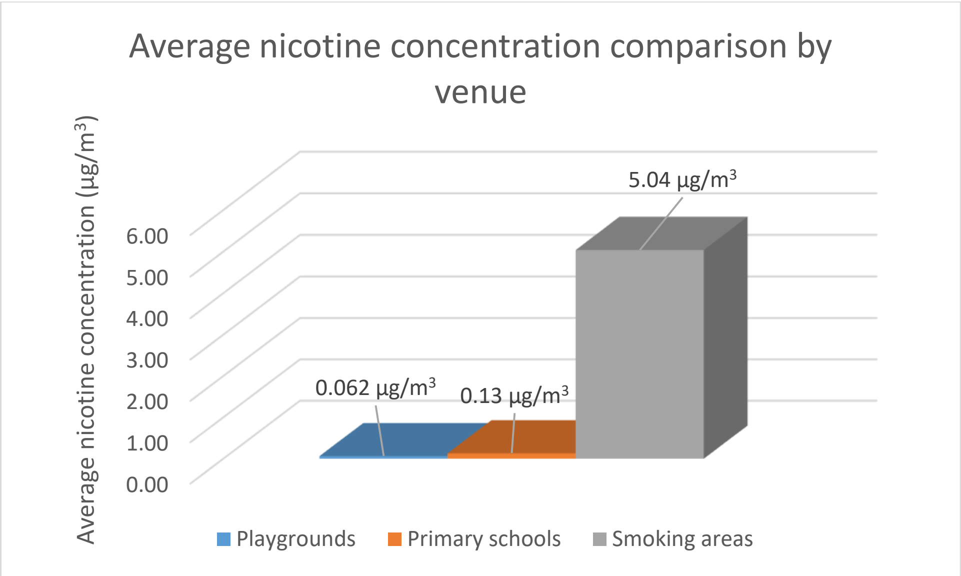


Figure 2.2: Comparison of average nicotine concentrations of all venues.

Figure 2.2 illustrates the overall averages for each venue type sampled. As expected, hospitality venues e.g. pubs, clubs and restaurant smoking areas had the highest vapour phase nicotine recordings.

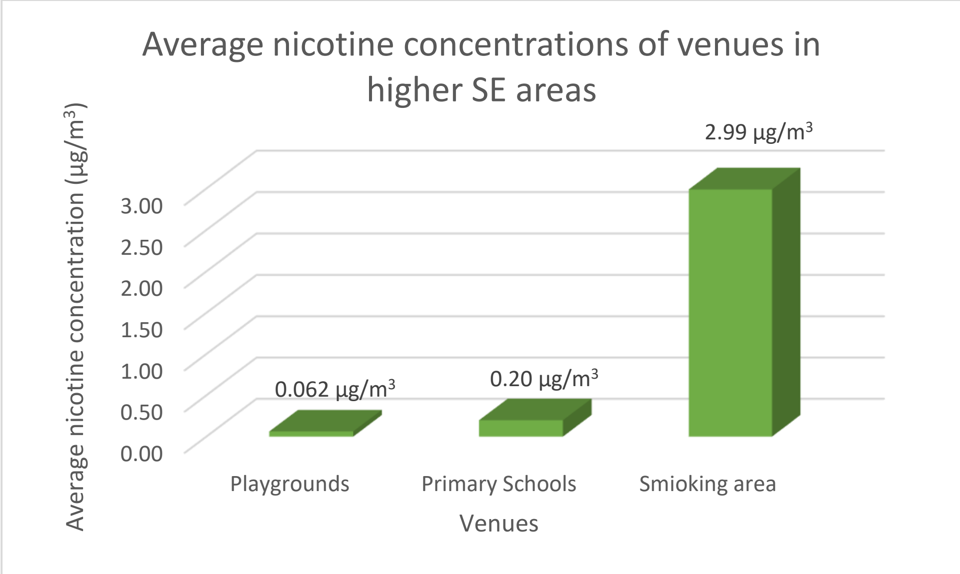


Figure 2.3: Average nicotine concentrations for venues located in higher SE areas.

Nicotine was not detected in 9 playgrounds while one had a concentration of 0.08 µg/m^3. Nicotine was detected at three primary schools. As expected, the highest concentrations were found in terraces of hospitality venues, averaging at 2.99 µg/m^3 as shown in figure 2.3.

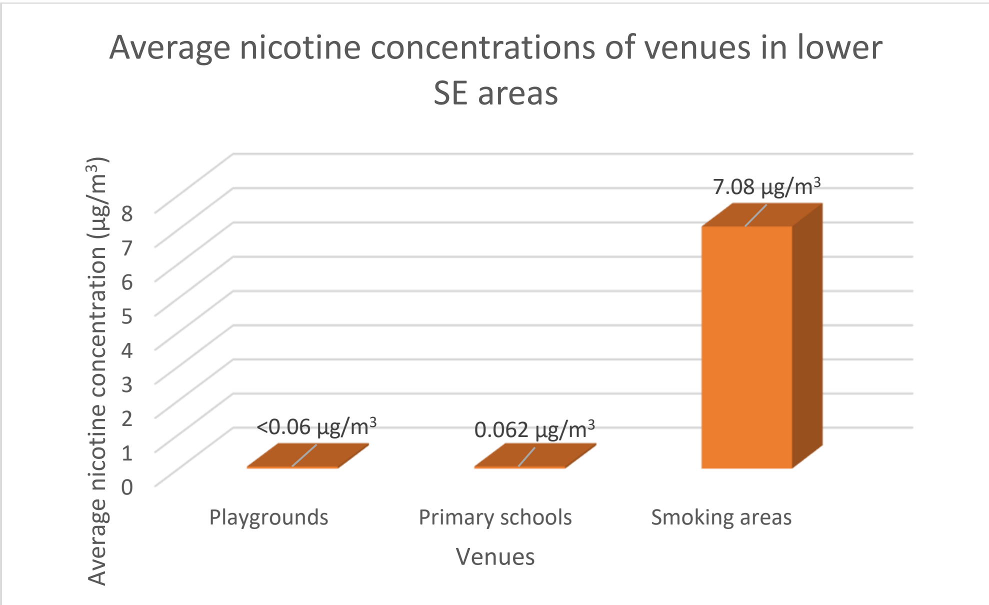


Figure 2.4: Average nicotine concentrations for venues located in lower SE areas.

Figure 2.4 illustrates the average nicotine concentrations recording within lower socioeconomic areas. Nicotine was not detected at any playground. Nine out of ten primary schools were also below the limit of detection. Again, as expected, terraces had the highest concentrations averaging at 7.08 µg/m^3.

The Project Consortium suggested a number of measures for urgent consideration. An increase in enforcement and monitoring of smoke-free legislation, particularly in workplaces and hospitality venues and an extension of smoke-free legislation to include outdoor areas of hospitality venues, playgrounds and school entrances were measures most notable to Ireland.

2.6.4 *TackSHS: Results from primary schools and playgrounds in 11 European countries*

Table 2.5 Data from primary schools.

Primary school variable	**EU result (n= 220)**	**Irish result (n= 20)**
Median (µg/m^3)	<0.06 (<0.06 to 0.119)	<0.06
Smoke smell % (n)	29.1% (64)	25.0% (5)
Smokers present % (n)	43.2% (95)	35.0% (7)
Cigarette butts present % (n)	75.0% (165)	60.0% (12)
Ashtrays present % (n)	14.6% (32)	0.0% (0)

Table 2.5 shows the Irish results in comparison to the European averages for nicotine and other recorded variables (Henderson *et al.*, 2020a). From their findings they concluded that smoking at the entrances to primary schools is a source of SHS exposure in European countries, which support extending smoking ban legislation to include a clear perimeter around primary schools.

Smoking is not regulated in playgrounds on a national level in Ireland however, local restrictions are provided for. Ireland was ranked at number 2 on the Tobacco Control Scale 2016 with an overall score of 70/100 (Joossens and Raw, 2016). Ireland is now ranked number 3 with a score of 73/100 (Joossens, Feliu and Fernández, 2019).

Table 2.6 Data from playgrounds.

Playground variable	**EU average (n= 219)**	**Irish average (n= 20)**
Median (μg/m^3)	< 0.06 (< 0.06–0.125)	< 0.06
Smoke smell % (n)	18.1% (36)	5.0% (1)
Smoking inside % (n)	19.6% (43)	15.0% (3)
Smoking outside % (n)	24.6% (49)	30.0% (6)
Cigarette butts inside % (n)	56.6% (124)	55.0% (11)
Cigarette butts outside % (n)	74.4% (163)	95.0% (19)

Table 2.6 illustrates the EU average for each variable measured next to the Irish averages. While smoke smell and recorded nicotine were low, smokers were present both inside and outside Irish playgrounds. The evidence of smoking shown through the presence of cigarette butts was high with 95% of playgrounds having butts <1m outside. The article concluded that there is evidence of SHS exposure in children's playgrounds and advocate for the introduction of, or better enforcement of smoking bans in and around children's playgrounds (Henderson *et al.*, 2020b).

Note: Results from the smoking areas had not been published by TackSHS investigators at the time of writing.

2.6.5 Conclusion

This project gave a valuable insight into smoking behaviours in Dublin, looking closely at socio-economic status, evidence of smoking, and exposure of children under 12. Evidence of smoking at playgrounds proved that smoking was taking place where it is known children will be present. Observed differences between the playgrounds SES saw the evidence of smoking 9.5 times higher in those located in low SE areas. In Primary schools, evidence of smoking was observed in 90% of lower SE areas and 30% at those located in higher SE areas. Nicotine concentrations were highest in terraces of hospitality venues, with those located in higher SE areas having notably lower concentrations. And so for this study, focus on the hospitality industry was chosen due to the discovery of non-compliances as well as provision of auxiliary bars, extending the licenced premises and placing employees in direct exposure of ETS.

2.7 COVID-19

In December 2019, a new strain of virus, COVID-19 caused by SARS-CoV-2 infection, which effected the respiratory system was identified in Wuhan, China. On February 29th 2020, the first confirmed case was reported in the ROI. Within two weeks, the WHO declared a pandemic. An Taoiseach at the time, Leo Varadkar announced that all schools, colleges and childcare facilities were to close followed shortly by all pubs on March 15th and hospitality venues on March 24th.

As previously discussed in this chapter, the health effects from tobacco use are well researched. Tobacco use is a known risk factor for severe disease and death from multiple respiratory infections and so, the question arose as to whether being a smoker placed you in a higher risk category for COVID-19 infection. A WHO scientific brief published in June 2020 concluded that the evidence available at the time did suggest that "smoking is associated with increased severity of disease and death in hospitalised COVID-19 patients" (WHO, 2020). Smoking has been associated with the "negative progression and adverse outcomes of COVID-19" more so than never smokers (Vardavas and Nikitara, 2020) (Patanavanich and Glantz, 2020).

The HSE reiterated the importance of quitting smoking particularly during the pandemic due to smokers increased risk of infection. The weakening of the lungs natural barriers from smoking was quoted in addition to the increased likelihood that smokers touch their faces and share cigarettes, further increasing their risk of infection. The effect of second-hand smoke particularly indoors and specifically children's vulnerability due to underdeveloped lungs and immune systems is also mentioned for its ability to "affect the body's natural resistance to fighting infections such as COVID-19" (HSE, 2020).

By July 2020, the health guidance was updated to reflect research that demonstrated "beyond any reasonable doubt that viruses are released during exhalation, talking and coughing in microscopic respiratory droplets" (Morawska and Milton, 2020). With this information, some countries began to impose tobacco related bans. In August 2020, numerous regions in Spain banned smoking in public places including streets where social distancing was not possible in order to slow the spread of the virus. However, this decision was quickly overturned on the basis that it limited fundamental rights. South Africa also banned the sale of tobacco and alcohol as part of a 21-day lockdown from March 26th to April 16th (Egbe and Ngobese, 2020). Neighbouring Botswana banned the sale and import of tobacco products during its COVID-19 restrictions. When their ban was lifted it was replaced with additional smoking restrictions that banned smoking in enclosed, indoor spaces in public or private workplaces.

As countries began to relax public health restrictions, in the context of COVID-19, the WHO suggested that Member States implement or sustain bans on water pipes (shisha), e-cigarettes and tobacco in public places, health facilities, public buildings, restaurants and cafes including designated smoking areas, educational buildings, transportation and workplaces, all in line with article 8 of the WHO Framework Convention on Tobacco Control (WHO, 2020).

In the ROI, reopening of the hospitality industry came about in late June with significant changes in how these industries were operated. The requirement for social distancing, significantly reduced capacity, which led to many businesses utilising their outdoor spaces as additional seating areas for food and drink service. A ban on smoking within these previously designated smoking areas was observed in some venues as part of their COVID-19 policies. A ban on indoor seating occurred before the highest level of restrictions were placed on the industry again in late October before reopening for full service indoors and outdoors on December 4th 2020.

As strict COVID-19 restrictions remain at the time of writing, it remains to be seen to what extent they will affect the hospitality and tobacco industries in terms of the number of businesses forced to close due to loss of income, huge reductions in tourism revenue and government spending on COVID-19 relief.

2.8 Conclusion

The purpose of this review was to revise and discuss literature past and present in the area of tobacco, health and subsequent legislation that has been enacted. The term “involuntary smoking” was coined early on in reports by the US Surgeon General and from then it can be seen written as second-hand smoking and environmental tobacco smoke exposure. ETS exposure began to become a subject of interest in occupational settings and researchers began concluding that indoor exposure for long periods of time were resulting in many health issues experienced by staff. These ranged from mild irritation of the eyes and respiratory system, to increased risk of cancers of the lung and coronary heart disease. It was then that research bodies began to insist that legislative measure be taken, resulting in the workplace smoking ban, enacted for the first time in Ireland in 2004. Those employees working within the hospitality industry saw the greatest benefits with overall improvements in their health observed.

However, it became clear that non-compliance was still regularly occurring with the Environmental Health Sector reporting 70 fines on businesses across the country for breaching section 47 of the Public Health (Tobacco) Act 2002 between 2014 and 2019 (HSE, 2019b). The issue of the designated smoking area is still one that places employees in the hospitality industry at risk and it is likely that current wording of the legislation is to blame as each individual can interpret it differently. Evidence of exposure accompanied with the real level of non-compliance is needed to notify the government that current legislation requires amendments to satisfactorily protect employees.

And finally, the impact of COVID-19 not only on this project, but the hospitality industry as a whole is yet to be defined but it is clear that the impact will be severe.

Chapter three: $PM_{2.5}$ collection methods, observational data recording and health assessment procedures.

3. Introduction

Environmental tobacco smoke (ETS) exposure has been most commonly assessed by questionnaires due to their simplicity and cost effectiveness in contrast to environmental monitoring. However, limitations of these assessments can include false/ under reporting and participants recall accuracy (Avila-Tang *et al.*, 2013). These studies have been incredibly valuable tools which have allowed researchers to assess individual exposure in various environments like the home and workplace contributing to epidemiological research across the world. Environmental monitoring of tobacco smoke constituents has been a reliable and repeatable measurement of second-hand smoke exposure within the area of public health. ETS exposure has historically been assessed by measuring airborne particulate matter (PM) and nicotine. In the 1980's it was established that cigarette smoking is a potent source of fine indoor airborne PM (Apelberg *et al.*, 2013). While early studies focused on questionnaire based self-reported exposure (USDHHS, 2006), micro environment and environmental monitoring began to become standard as the discipline shifted towards obtaining quantitative scientific evidence to further back up research. Many recent studies have monitored tobacco constituents like PM and airborne nicotine as a specific means of measuring the presence of smoke as well as second-hand exposure. Additionally, urinary and salivary cotinine levels are used as biomarkers of tobacco exposure (Menzies *et al.*, 2006) (Semple *et al.*, 2007), referred to in section 2.4.2 Review of health benefits associated with comprehensive smoke-free laws. Health effects of ETS exposure have also previously been measured using spirometry tests and patient self-reported symptoms (Eisner, Smith and Blanc, 1998) (Menzies *et al.*, 2006) (Goodman *et al.*, 2007) (Larsson *et al.*, 2008) (Issa *et al.*, 2011).

For this study, a quantitative approach was employed to gather data as this is standard practice for second-hand smoke exposure assessment demonstrated in numerous studies

(Moshammer, Neuberger and Nebot, 2004) (Repace, 2006) (Goodman *et al.*, 2007) (McCaffrey *et al.*, 2012) (López *et al.*, 2013) (Fu *et al.*, 2016) (Barnoya *et al.*, 2016) and allowed for conclusions to be drawn based on the statistical findings. Observational data was also recorded through observational forms, recording elements of the smoking area. These included, but were not limited to, the presence of a roof, number of walls, size, presence of an operating auxiliary bar counter, number of patrons, number of smoking patrons, number of staff and frequency or time spent in the area, and presence of children under 12. This was done to gain an insight into the current state of smoking areas in Dublin, giving an insight into how the current legislation is being complied with and if there is a necessity to revisit the legislation in order to protect public health. This data also allowed for assessment of the environments hospitality staff work in. In addition to this, the immediate health effects on healthy non-smokers exposed to ETS were observed in order to estimate the possible health effects of hospitality employees during and after their shifts.

3.1 Selection of venues

To allow for comparison of results with the pilot study, a similar method was used to select the venues to achieve variation in venue size, location and socio-economic status. 100 venues were chosen using the Pobal HP Deprivation Indices, layer list: 2016 – by small area, located in the online Pobal Maps Portal (Pobal, 2016). The venues were characterised by socio-economic status of the area they were located in: low (n= 10), medium (n= 34), high (n= 56). Google Maps was also used simultaneously to ensure an even spread of venues across the Greater Dublin Area. Venues without a designated smoking area were excluded. Venues were recorded and assigned a venue code in a master file. This file was stored in a password protected location to ensure confidentiality as the venues were not identifiable at any point during the study.

While socioeconomic status was recorded in line with the previous TackSHS protocol, it is important to note that venue SES and patron SES may differ and without customer interviews, this could not be established. For example, many venues located within Dublin City Centre are visited by customers from a multitude of backgrounds including local office workers, Irish and international tourists, college students and members of the public who reside outside the city centre itself. In contrast, venues located in suburban or rural locations are more likely to have a local patronage and in turn the venue SES will be more representative of their customer's SES.

3.1.1 COVID-19

Due to COVID-19, 13 of the pre-selected venues closed in March 2020 and remained closed for the remainder of the sampling period. A further 12 venues were incomplete due to public health restrictions which came into effect October 22nd. The final number of venues sampled for this project was 75 (low (n= 7), medium (n= 27), high (n= 41). A confidence level of 90% and 80% power was found for a sample size of 75.

3.2 Instrumentation and observational data collection

3.2.1 Air sampling device

Second-hand smoke exposure was quantified using the TSI Inc. SidePak AM510 Personal Aerosol Monitor, which has the capabilities to record fine particles $PM_{2.5}$. The TSI SidePak is a compact, portable battery-operated laser photometer that measures airborne particle mass-concentration in units of miligrams per cubic metre (mg/m^3). The device has a 12-character x 2-line LCD displaying aerosol concentrations in real time. Information is stored on the device and downloaded by the user via the TrakPro software and USB communications cable.

The SidePak was fitted with a $PM_{2.5}$ impactor and had a flow rate set to 1.7 litres/ minute with a logging frequency of 1 minute. The calibration certificate concluded that the instruments precision and accuracy are good applying the gravimetric K factor of 0.493.

3.2.2 Coding samples

In order to ensure confidentiality and anonymity, each venue was pre-assigned an identification code as follows: SA01-SA100. Although 100 venues were not sampled, the pre-assigned IDs remained in use for all venues.

Volunteers partaking in the health effect research were assigned codes as follows: HE01-10.

These codes were recorded on the consent form, venue observational form, health effect form and smoke exposure questionnaire to allow for data analysis (all available in appendix 7.6).

3.2.3 Control

Background ambient air quality was recorded in various locations around Dublin city. Each venue was also sampled inside (the smoke free area) for 2- 5 minutes to ascertain the particulate levels present where smoking was prohibited. At venues where a health volunteer was present, air monitoring began before entering the smoking area whilst carrying out pre exposure tests, continued during exposure, and after leaving the smoking area whilst post exposure health parameters were assessed.

3.2.4 Health Assessments

As part of the TobaccoFree Research Institute of Ireland "New approaches to monitoring exposure to air pollution and health effects" project, a control group of 10 health non-smokers were required. As the employment partner, this was carried out by the researcher with approval to use the results as a pilot study for hospitality employee exposure assessments. Ethical approval was sought by TFRI and approved by then Dublin Institute of Technology (see appendix 7.6.1). As part of TFRI protocol, had any abnormal readings been recorded, the volunteer would have been advised to visit their GP assuming no urgent action was required. If the volunteer was symptomatic, a hospital referral would be initiated by TFRI colleagues (Clinical Nurse Specialist and Respiratory Consultant). If a series of abnormal or high readings were recorded after multiple readings, the device would have been recalibrated to ensure accurate readings.

In order to assess the health effects of ETS exposure, ten healthy non-smokers volunteered to take part in the study (5 males, 18 – 53 years old, 5 females, 21 – 58 years old). Volunteers were peers, relatives and colleagues of the researcher. Their health was assessed measuring exhaled CO levels, spirometry, and PEF.

Exhaled CO, peak flow and spirometry were measured by the researcher pre and post each sampling period while peak flow was also measured during exposure, to ascertain any immediate health effects on the 10 volunteers. The CareFusion SmokeCheck CO Monitor indicated the level of each volunteer's eCO as a result of second-hand smoke exposure. This is the validation method of choice for smoking cessation services as it is low cost, compact, easy to use and provides immediate results. The monitor displayed parts per million (PPM) of eCO on the LCD display. The monitor features single-button operation and coloured light indicators to simplify volunteer understanding of the process:

- Green: 0 to 6ppm
- Amber: 7 to 10ppm
- Red: 11 to 20ppm

- Flashing red and alarm: >20ppm

In previous studies, average values of exhaled CO of non-smokers has been 1.26 ppm (Cunnington and Hormbrey, 2002) and 3.61+2.15 ppm (Deveci *et al.*, 2004) for example.

A spirometer (CareFusion MicroLoop Handheld Spironmeter SN: 105-10697) was used to test lung function. This test measures the volume and speed of air exhaled. Forced expiratory volume in one second (FEV1) is the amount of air exhaled by force in one second while forced vital capacity (FVC) is the total volume of air exhaled in one breath.

Peak expiratory flow (PEF) is the maximum flow exhaled from the lungs and was measured using a Mini-Wright Standard Range Peak Flow Meter. "Normal" peak flow varies according to the person's age, height and sex but adults range between 400-700 litres per minute. The chart showing the predicted normal values for peak expiratory flow when using the PFM can be found in appendix 7.4. From this chart, the variances are clear not only between male and female, but also, age and height.

Note: see appendix 7.4 for breakdown of health assessments.

3.3 Air sampling method

Sampling of smoking areas commenced in May 2019 for 12 months which allowed for seasonal differences to be observed (noted limitation of the pilot study). Monitoring was performed without notifying the premises owner, employees or customers to allow for spontaneous sampling. If questioned, information was provided about the investigation. Measurements were taken for 45 minutes - 1 hour either at night/evening time or during the day/afternoon time and on both weekend and weekdays. Based on previous studies of smoking areas, the most central table was chosen where possible. This was to ensure, as much as possible, that there was no smoke source within <1 metres of the sampling device. The results for each location were downloaded from the machine daily to ensure accurate records were kept and memory on the equipment was kept free. Prior to each sampling, the SidePak was charged fully overnight and zero calibrated applying the absolute filter supplied by the manufacturer.

3.3.1 Observational data collection

Observational forms were designed to record various attributes of the smoking areas including estimated size of the area, relative humidity, socioeconomic status, smoking area compliance and physical features (see appendix 7.5). In order to determine compliance, the legislation was referred to and the physical aspects of the smoking area were noted.

"*A place or premises, or a part of a place or premises, that is wholly uncovered by any roof*", "*an outdoor part of a place or premises covered by a fixed or movable roof, provided that not more than 50 per cent of the perimeter of that part is surrounded by one or more walls or similar structures (inclusive of windows, doors, gates or other means of access to or egress from that part)*" (Irish Statute Book, 2004).

Whether the area had a fixed roof or an awning (a movable roof), or both were all options in addition to the perimeter and what the perimeter was made of e.g. the area had an awning that was closed and the perimeter consisted of two permanent walls and two glass screens, deeming the area non-compliant as more than 50% of the perimeter of that roof was made of a wall or similar structure.

The ambient $PM_{2.5}$ recorded by EPA monitoring sites located across Dublin in 2019 had annual mean $PM_{2.5}$ concentrations ranging from 8 – 11 µg/m^3 (EPA, 2019a). The EPA Air Quality Calendar was then used to record daily measurements at the site closest to the smoking area sampled that day. These are presented alongside the smoking area results in table 4.9.

3.4 Data analysis

According to the SidePak AM510's calibration certificate, the instruments precision and accuracy were good applying the gravimetric K factor of 0.493. This correction was applied to all measurements. Data was retrieved from the SidePak using the TSI TrakPro Data Analysis Software. Concentrations were recorded in mg/m^3 and were converted to µg/m^3.

Particulate Air pollution measurements are traditionally expressed as µg per metre cubed. As such they are expressed as the amount of particulate matter collected per of air sampled.

The gold standard system to measure $PM_{2.5}$ as specified by the European Union is the gravimetric method, where air is drawn through a filter at a specified flow rate (usually for 24 hours). The flow design is such that only $PM_{2.5}$ particles reach the filter. The filter is weighted in a humidity controlled environment both before and after exposure, and the mass of collected particulate is calculated. The disadvantage of this system is that there is no time resolution.

Most portable devices use optical systems and based on the light scattering the number of particles present in a sample can be counted. This type of system, as used in the SidePak, gives us real time data. The pump and inlet design mean only the $PM_{2.5}$ size fraction reaches the sampling chamber.

Statistical analysis was completed mainly using the data analysis package in Microsoft Excel. Mean, p-values and correlations can be viewed in full in appendix 7.7. Rstudio was utilised for the display of results mainly in bar graphs and plots.

3.5 COVID-19 observations

As a result of COVID-19 restrictions, the sampling timeline was altered. Sampling took place from May 2019- March 2020 and recommenced in July 2020 – October 2020. While monitoring still occurred without notifying the premises, advanced booking was required for the majority of venues due to public health requirements and guidelines for the July – October period of reopening. All customers had to remain seated and substantial meals of >€9 were required in order to purchase alcohol. The most central table was therefore not always assigned however, due to social distancing between tables, there was still no smoke source within <1m of the sampling device. Where public health guidelines were not being adhered to, the venue was removed from the list and replaced if possible. When COVID-19 restrictions were implemented indoor readings could not take place in some venues. Some venues banned smoking within their outdoor areas when outdoor dining was in place, however, only one venue was visited where this was implemented.

3.6 Ethical consideration

The study was approved by Technological University Dublin's Ethics Committee. Approval was sought by the project supervisor using the TU Dublin online ethics portal. The project method was risk assessed and approved. All site visits were carried out in line with Government guidelines for that time in order to protect the health of all involved.

Ethical approval was sought by TobaccoFree Research Institute for the health assessment of healthy non-smokers.

Chapter four: Data analysis and interpretation

4. Introduction

In this chapter, the results of the particulate matter 2.5 ($PM_{2.5}$) measurements, observational data and health assessments are presented. Beginning with the smoking area observations and $PM_{2.5}$ concentrations, followed by a more in depth look at the smoking areas physical makeup and the subsequent effect if any on $PM_{2.5}$ concentrations. These are followed by the results of the health assessments where the effects of environmental tobacco smoke exposure on the individual is reported.

Non-compliant smoking areas are defined as *an outdoor part of a place or premises covered by a fixed or movable roof, provided that not more than 50 per cent of the perimeter of that part is surrounded by one or more walls or similar structures (inclusive of windows, doors, gates or other means of access to or egress from that part),* and accounted for 60% of venues sampled.

Staff were observed spending some time within the smoking areas of 88% of venues. As stated in Chapter three section 3*.2.2 Coding samples*, 100 venues were not sampled and the pre-assigned IDs remained in use for all venues which range from 1 - 100. The statistical analysis of this chapter is displayed in full in appendix 7.7. In this chapter the p-value is written as $p < .001$ where the value is less than 3 decimal places and the full value can be viewed in appendix 7.7.

4.1 Smoking area details

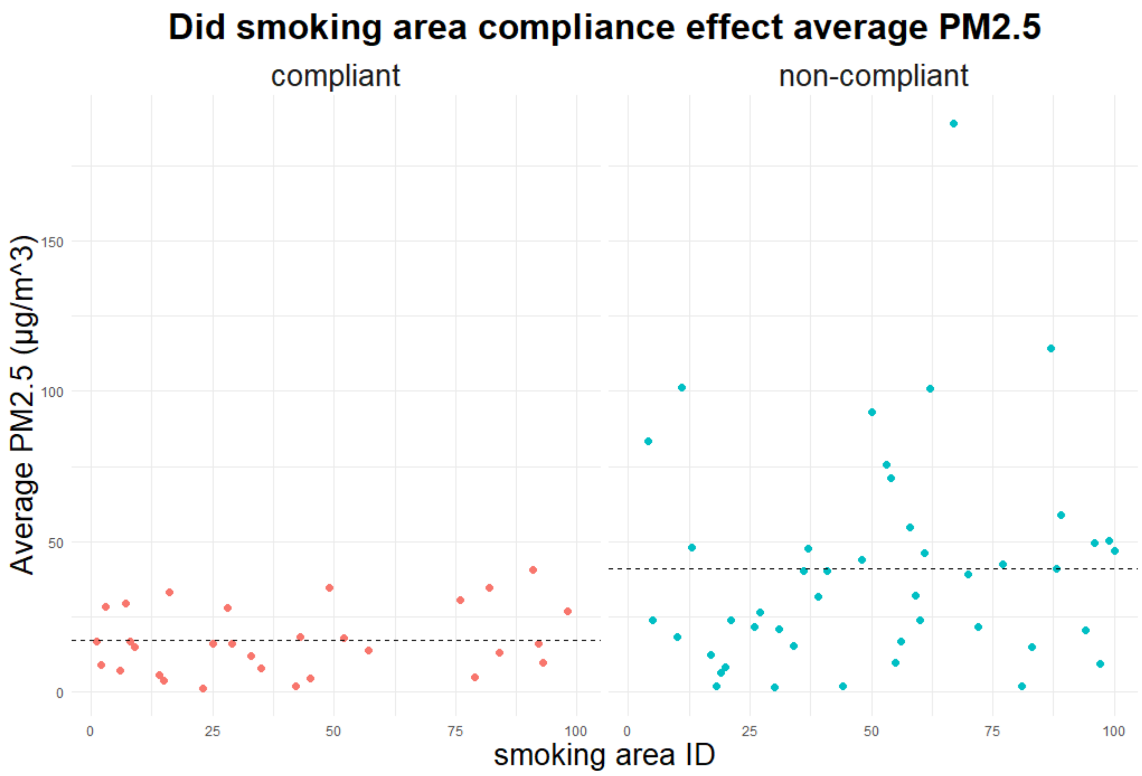


Figure 4.1: Do non-compliant smoking areas effect average $PM_{2.5}$.

Compliance with legislation was observed for each smoking area visited, 60% (n= 45) were deemed non-compliant with the Public Health (Tobacco) Acts, while 40% (n= 30) were compliant as shown in figure 4.1. Non-compliant smoking areas had an average $PM_{2.5}$ of 41.1 µg/m^3. Compliant smoking areas had an average $PM_{2.5}$ of 17.2 µg/m^3. Compliance was determined based on roof or lack thereof and roofed area perimeter as mentioned in Chapter three section *3.3.1 Observational data collection*. The results show a statistically significant ($p < .001$) difference in $PM_{2.5}$ levels between compliant and non-compliant smoking areas. The t-Test was repeated without the outlier (189 µg/m^3) and the p-value remained statistically sound ($p < .001$).

4.1.1 *Socioeconomic status of hospitality venues*

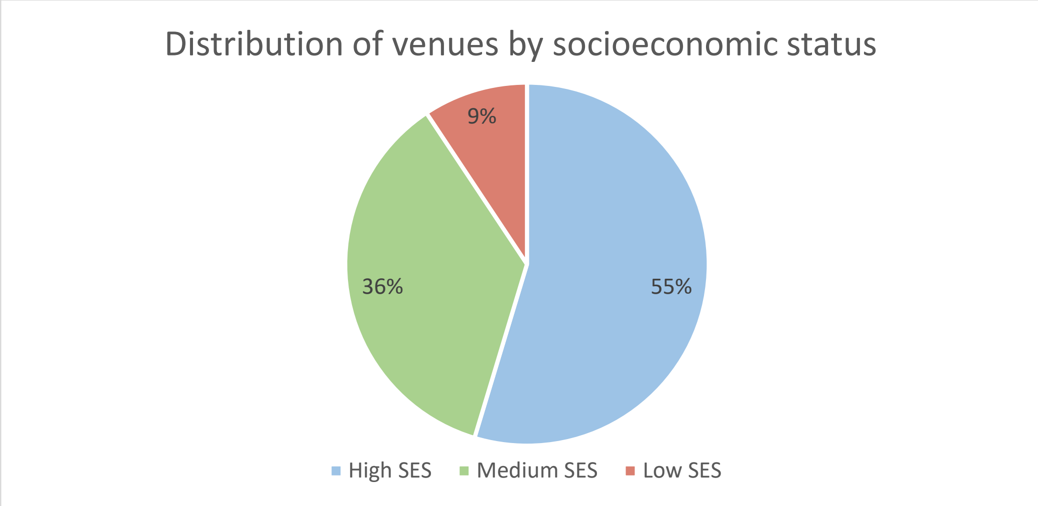


Figure 4.2: The socioeconomic status of hospitality venues visited.

Figure 4.2 shows the distribution of the smoking areas across Dublin by the socioeconomic status of the venue location. Data taken from the Pobal deprivation indices: 2016 census. The chart demonstrates how Dublin was skewed more affluent and so the majority of smoking areas were in venues located in areas deemed to be more affluent by the Pobal mapping software. Forty-one smoking areas were located in higher socioeconomic areas, 27 in medium socioeconomic areas and 7 in lower socioeconomic areas.

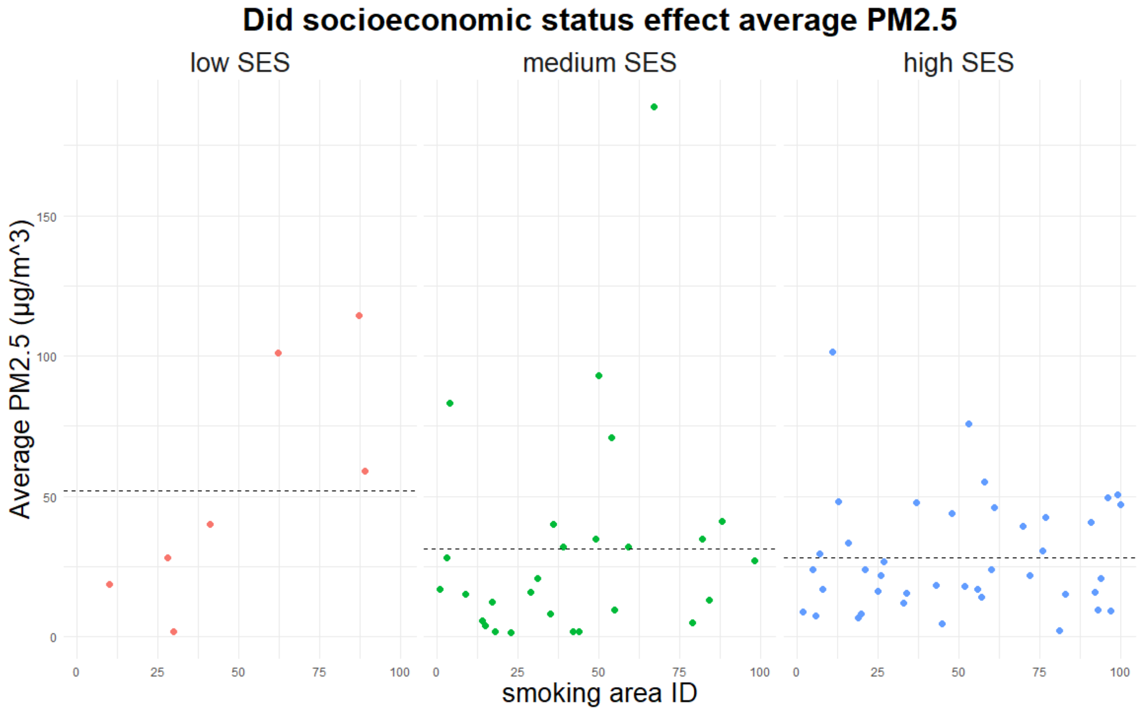


Figure 4.3: Did the socioeconomic status of the smoking areas location affect $PM_{2.5}$.

Figure 4.3 illustrates that when the mean $PM_{2.5}$ was found for smoking areas as per their socioeconomic status, smoking areas in lower socioeconomic areas measured higher with an average $PM_{2.5}$ of 51.8 µg/m3. Smoking areas located in medium and higher socioeconomic areas had similar averages of 31.2 µg/m^3 and 28.3 µg/m^3 respectively. When $PM_{2.5}$ values for low and medium socioeconomic areas were compared the *p*-value = 0.3. However, it must be noted that the number of smoking areas located in high socio-economic areas was higher than those located in low socio-economic areas, thus affecting the mean.

Table 4.1: $PM_{2.5}$ measurements across all smoking areas by their socioeconomic status.

	Low SES (n= 7)	Medium SES (n= 27)	High SES (n= 41)
Mean $PM_{2.5}$	51.8	31.2	28.3
Max mean $PM_{2.5}$	114.4	189	101.4
Min mean $PM_{2.5}$	1.8	1.4	2.2

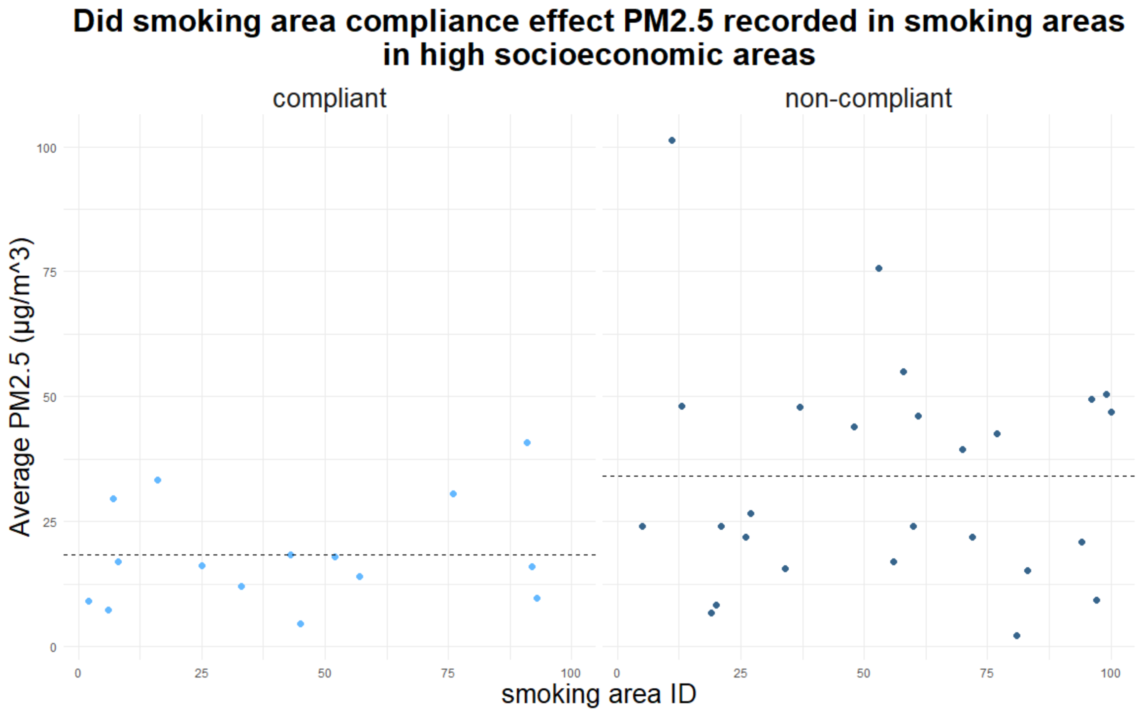


Figure 4.4: Smoking areas in high socioeconomic areas.

When smoking areas were filtered by their socioeconomic status, the difference in mean $PM_{2.5}$ remained significant (p =.005) as displayed by figure 4.4. Within higher socioeconomic areas, 15 smoking areas were compliant with a mean $PM_{2.5}$ of 18.4 µg/m^3. Twenty-six smoking areas were non-compliant with a mean $PM_{2.5}$ of 34 µg/m^3.

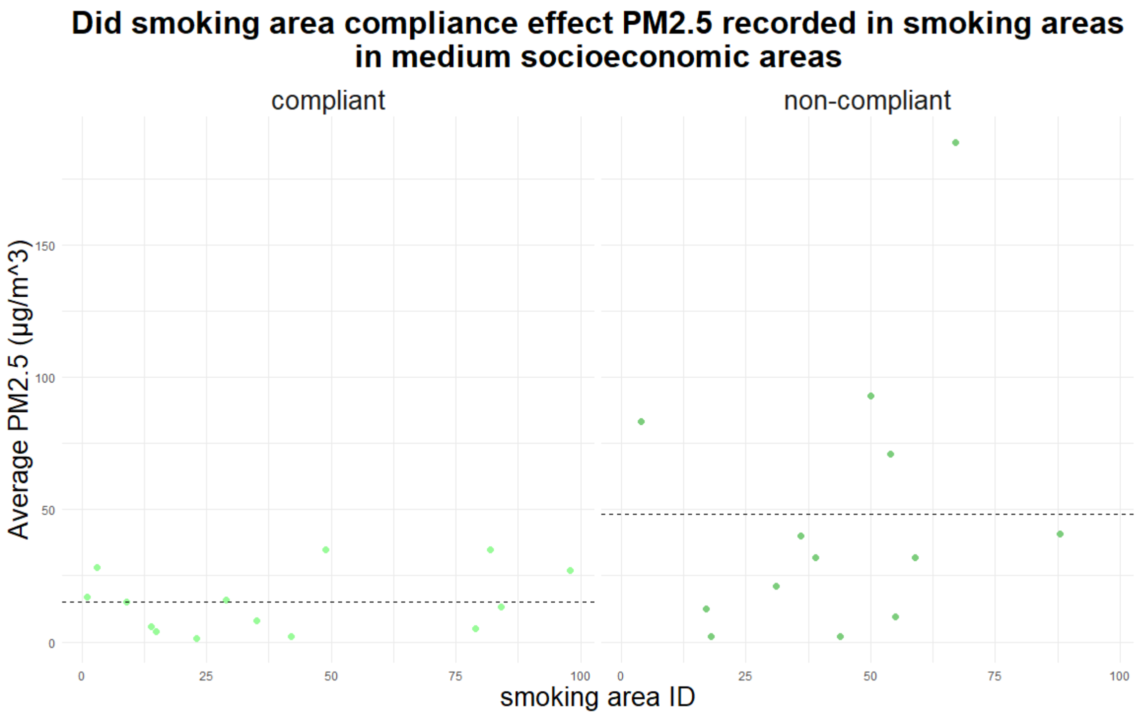


Figure 4.5: Smoking areas in medium socioeconomic areas.

Within medium socioeconomic areas, 14 smoking areas were compliant with a mean $PM_{2.5}$ of 15.2 µg/m^3. Thirteen smoking areas were non-compliant with a mean $PM_{2.5}$ of 48.3 µg/m^3 (p = .04) as shown by the grey line in figure 4.5.

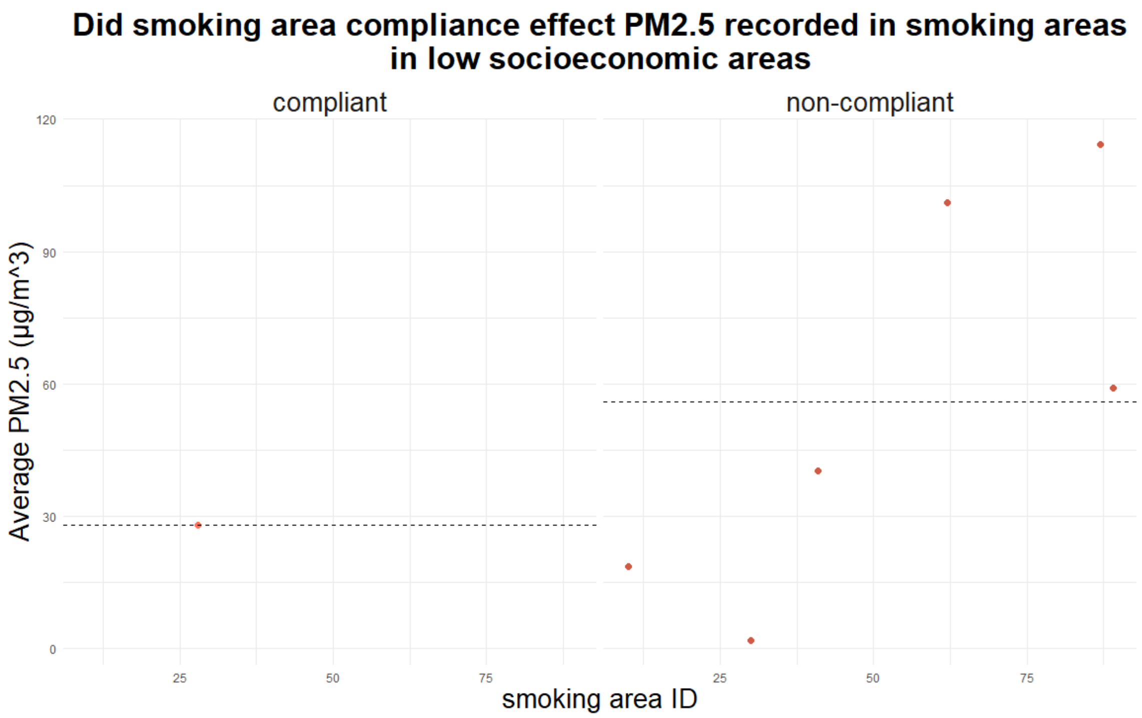


Figure 4.6: Smoking areas in lower socioeconomic areas.

As figure 4.6 illustrates, only seven smoking areas were located in lower socioeconomic areas. Within low socioeconomic areas one smoking area was compliant with a mean $PM_{2.5}$ of 28 µg/m^3. Six smoking areas were non-compliant with a mean $PM_{2.5}$ of 55.8 µg/m^3. Due to the number of smoking areas located in lower socioeconomic areas, statistical analysis was not possible however, it is important to note that 86% of smoking areas within this socioeconomic category were non-compliant. The small number sampled is not representative and would benefit from a larger sample size in order to make comparisons between the socioeconomic areas.

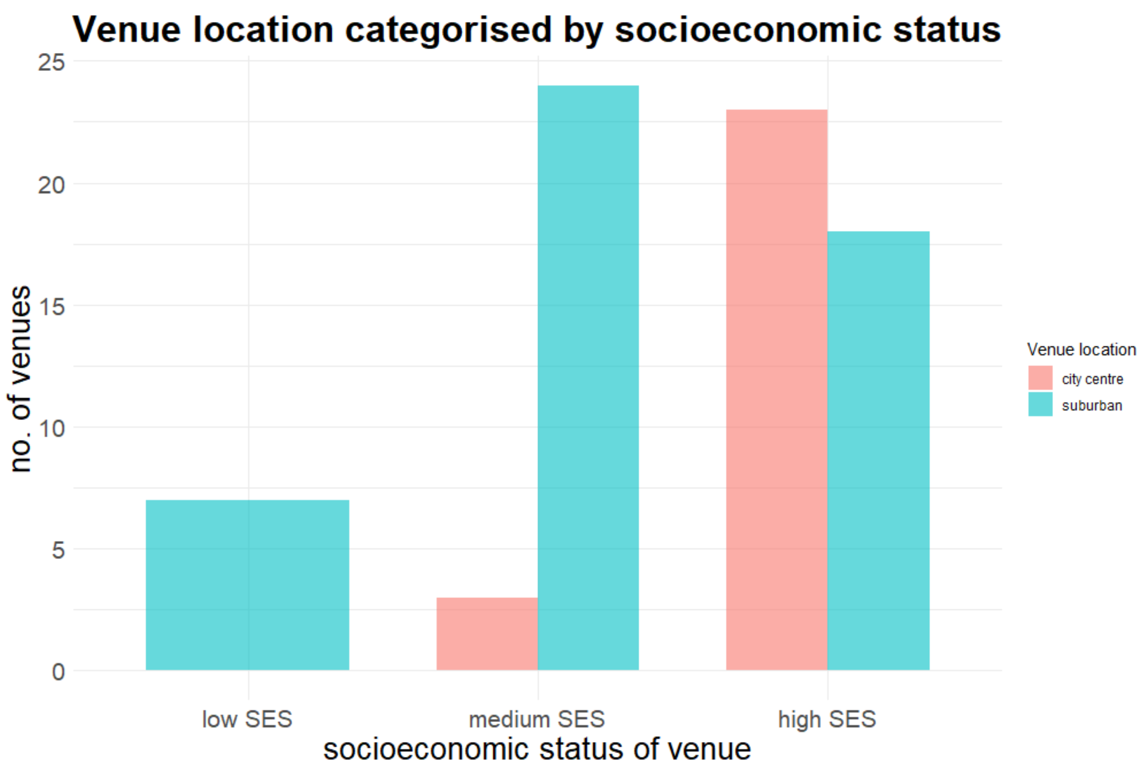


Figure 4.7: Venue location categorised by socioeconomic status.

In figure 4.7 the venues were categorised by their area socioeconomic status in order to look at the distribution across Dublin. The venues located in the city centre were in predominantly high SE areas while the majority of venues in medium SE areas were in suburban parts of Dublin. Venues visited in low SE areas were all located in the suburbs.

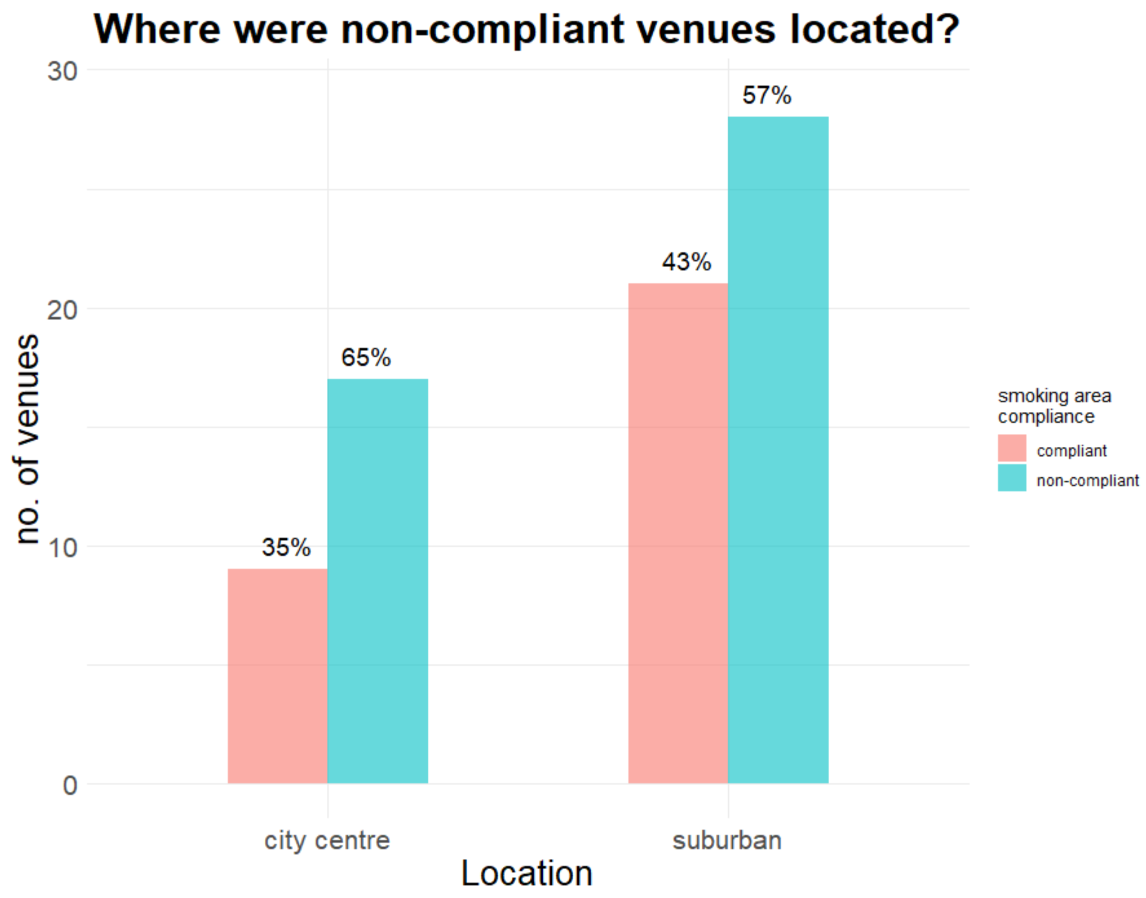


Figure 4.8: Smoking areas location within Dublin.

In figure 4.8, the smoking areas are displayed by their location. Within Dublin's city centre, 35% (n= 9) of smoking areas were compliant while 65% (n= 17) were non-compliant. In the suburbs, 43% (n= 21) of the smoking areas were compliant while 57% (n= 28) were non-compliant. When only non-compliant smoking areas were looked at, 38% (n= 17) were located in Dublin's city centre while 62% (n= 28) were in suburban/ residential areas. The overall distribution of venues (35% city centre, 65% suburban) demonstrates that non-compliance was evenly distributed across the county.

4.1.2 Smoking area perimeter materials

In smoking areas where the perimeter made up more than 50% of the area, average $PM_{2.5}$ levels were higher (37.3 μg/m^3) than in those areas with a perimeter of less than 50% (16.6 μg/m^3) (p < .001). See appendix 7.7.7. The following graphs and tables help determine whether perimeters and roofs had any effect on the average $PM_{2.5}$ recorded. For the purpose of reporting, perimeter materials were condensed to allow for concise graphs. Areas that had recorded a combination of permanent walls, permanent half walls, glass or hedges were renamed as combination perimeters as seen in the following graphs.

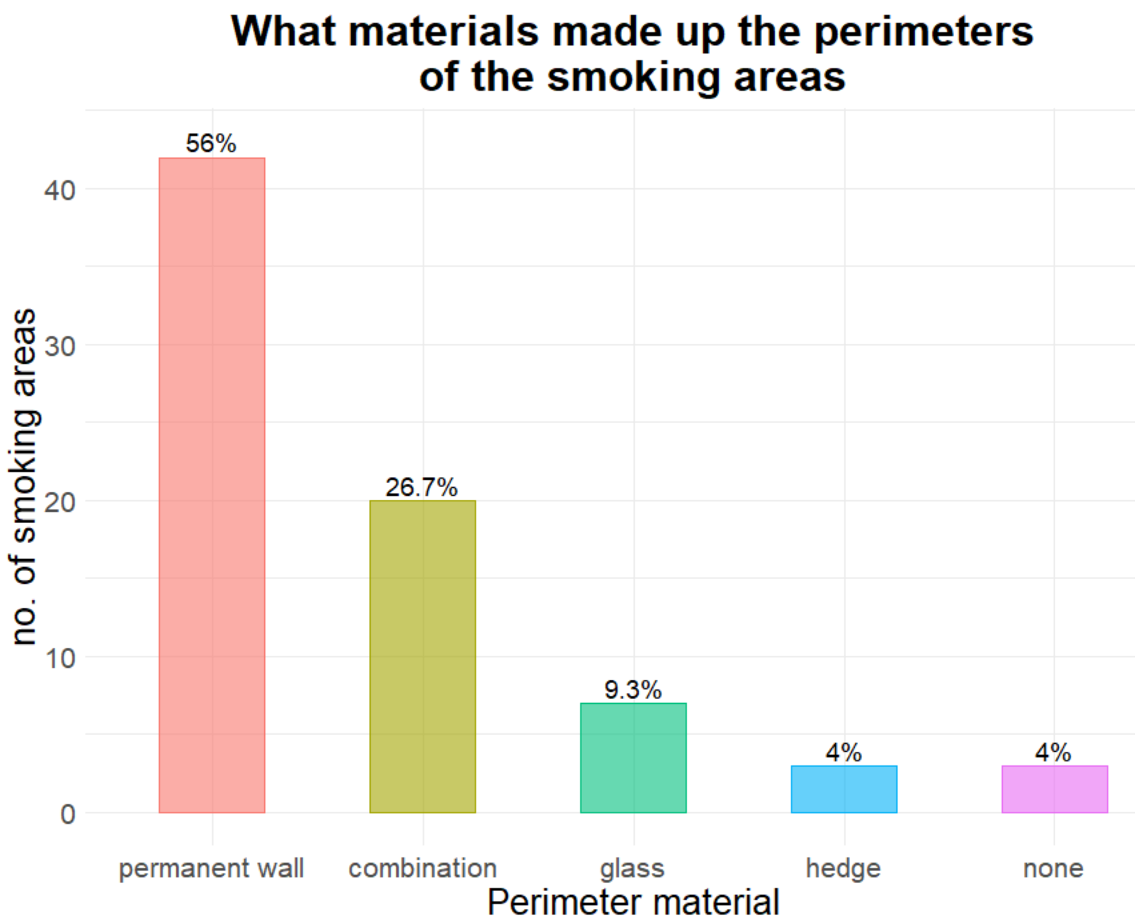


Figure 4.9: Smoking area perimeter materials.

As part of the observational data, the physical makeup of the designated smoking area was recorded and is displayed in figure 4.9. As the perimeter of an area with a roof is stipulated within the legislation, the perimeter materials were noted to determine whether it effected $PM_{2.5}$ within the smoking area. As displayed in the above graph, 56% (n= 42) of smoking areas had perimeters made up of permanent walls, 26.7% (n= 20) were made up of a combination of permanent walls and other structures, 9.3% (n= 7) were surrounded by glass perimeters, 4% (n= 3) hedge and 4% (n= 3) of smoking areas had no perimeter structures present.

Table 4.2: Did perimeter material effect mean $PM_{2.5}$ within smoking areas.

Wall type	**Mean $PM_{2.5}$**
Permanent wall	34.6
Combination	34.2
Glass	23.8
Hedge/ no wall	9.7

As shown in table 4.2, overall, $PM_{2.5}$ remained at similar levels where a permanent perimeter fixture was present. Areas surrounded by permanent walls or a perimeter consisting of a combination of two or more different elements were significantly higher than areas surrounded by just hedges or with no perimeter fixtures at all, due to increased air flow through the smoking areas ($p < .001$).

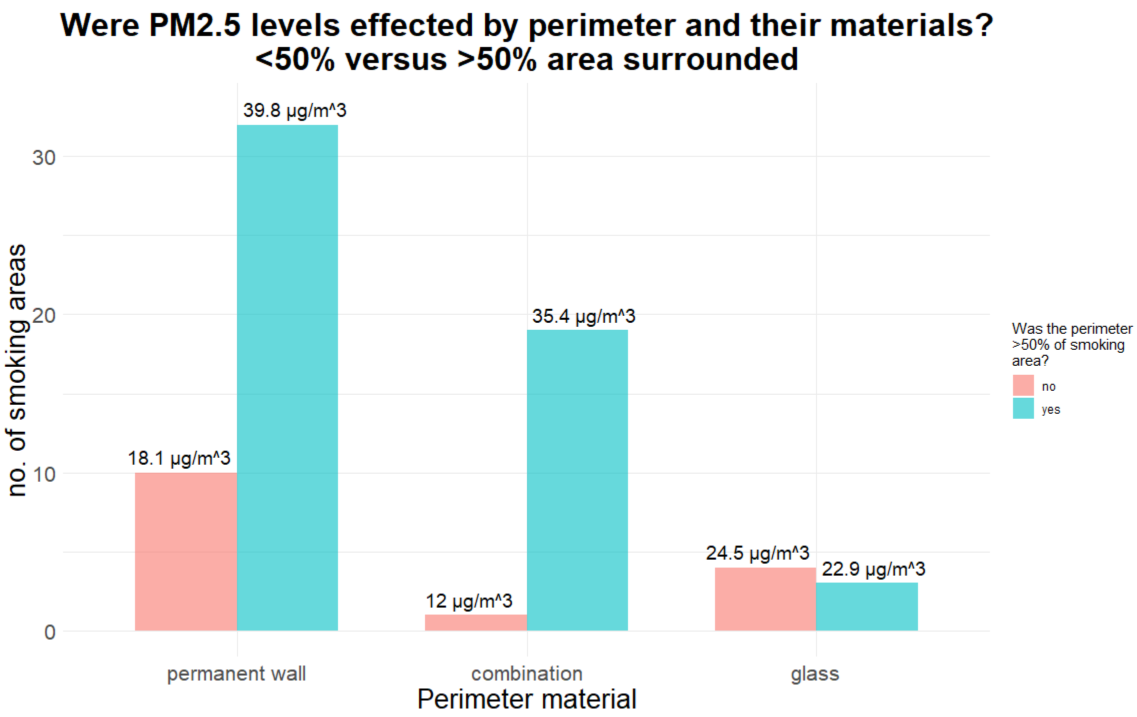
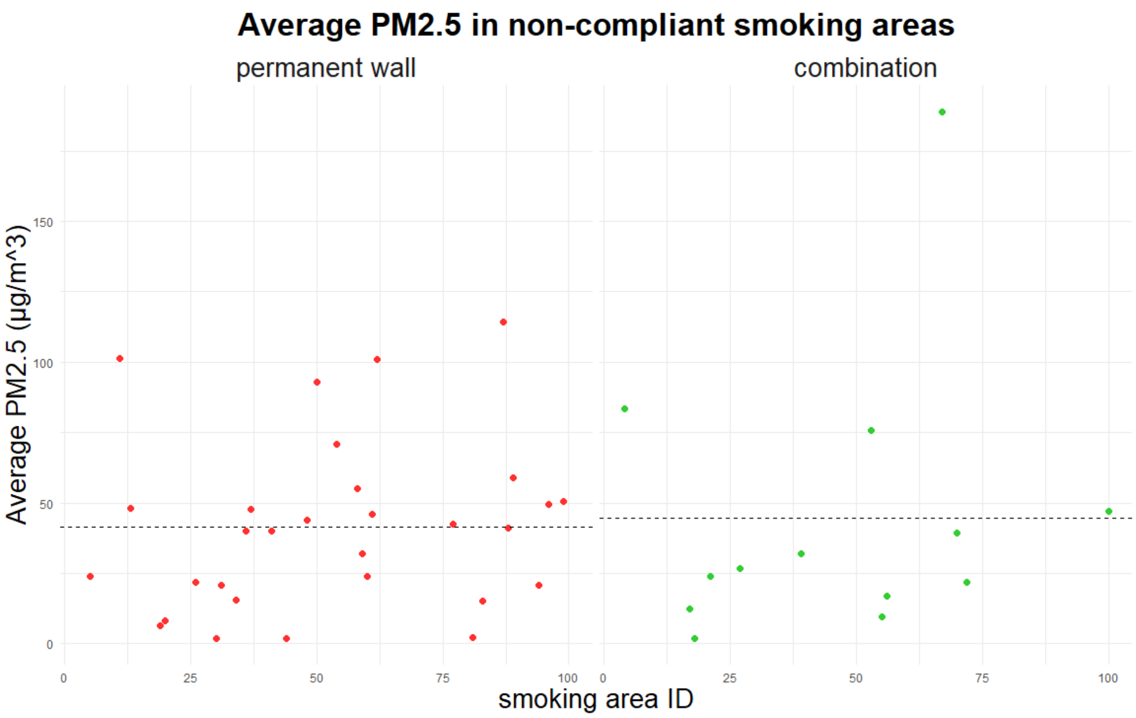


Figure 4.10: A comparison of smoking areas by their perimeter and the effect they had on mean $PM_{2.5}$ levels.

In smoking areas that had a perimeter of more than 50%, the perimeters were made up of various materials. Permanent full height walls were noted in 59.3% (n= 32), 35.2% were a combination of permanent walls and other structures (n= 19). While 5.5% were glass perimeters (n= 3). In figure 4.10, the effect of smoking area boundary materials was looked at and when $PM_{2.5}$ was observed for each, significant differences were seen in smoking areas with permanent walls (p = .002). While glass perimeters saw similar $PM_{2.5}$ measurements regardless of area coverage (p = .89). The number of smoking areas with perimeters made up of a combination of materials did not allow for meaningful statistical analysis.



Note: There were only two non-complaint smoking areas with a glass perimeter and so these were omitted as they would not provide for a meaningful discussion.

Figure 4.11: Average $PM_{2.5}$ in non-compliant smoking areas categorised by the perimeter materials.

Non-compliant smoking areas that consisted of a roof with a perimeter of >50% that was made up of either permanent walls (n= 30) or a combination of permanent walls and other structures (n= 13) are displayed in figure 4.11. $PM_{2.5}$ was similar in the non-compliant smoking areas 41.3 µg/m^3 and 44.6 µg/m^3 (p = 0.8). When the outlier within the combination wall type dataset was omitted from the analysis, the p-value remained non-significant, p = 0.3 (see appendix 7.7.10).

4.1.3 Smoking area roof:

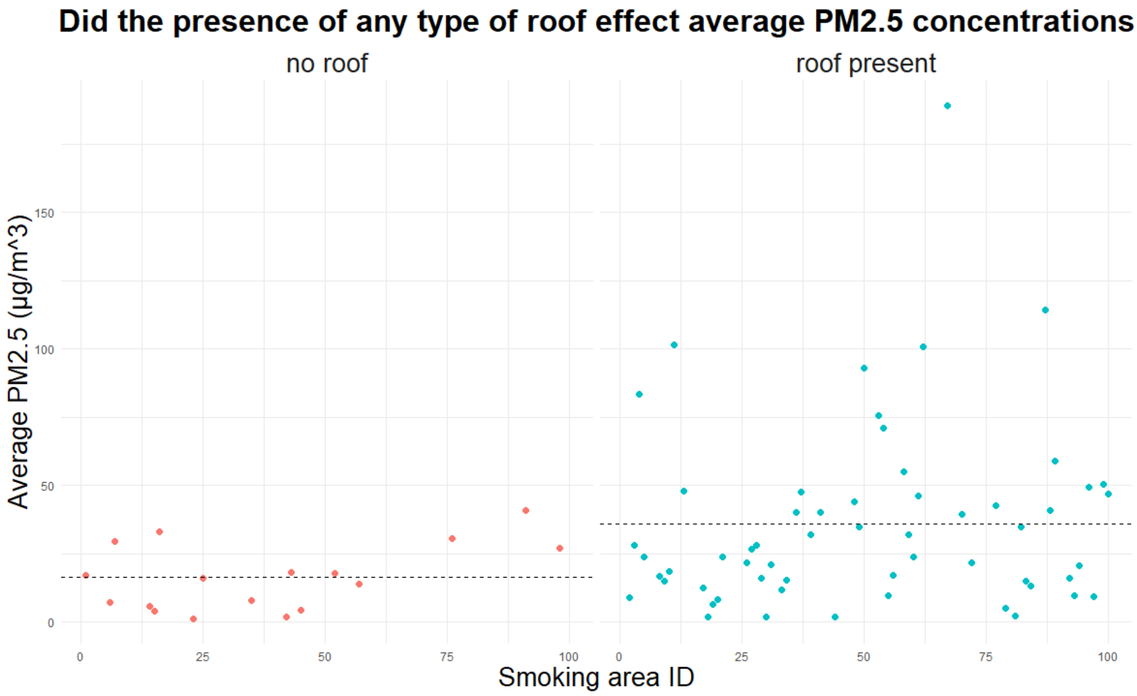


Figure 4.12: The presence of a roof effected $PM_{2.5}$ concentrations.

77.3% of smoking areas had a roof at the time of sampling illustrated in red in figure 4.12. There was a statistically significant difference found when smoking areas with any type of roof and without a roof structure of any kind were compared (p = .001), see appendix 7.7.11. Smoking areas with no roof had an average $PM_{2.5}$ of 16.3 µg/m^3 compared to those with a roof, 36 µg/m^3.

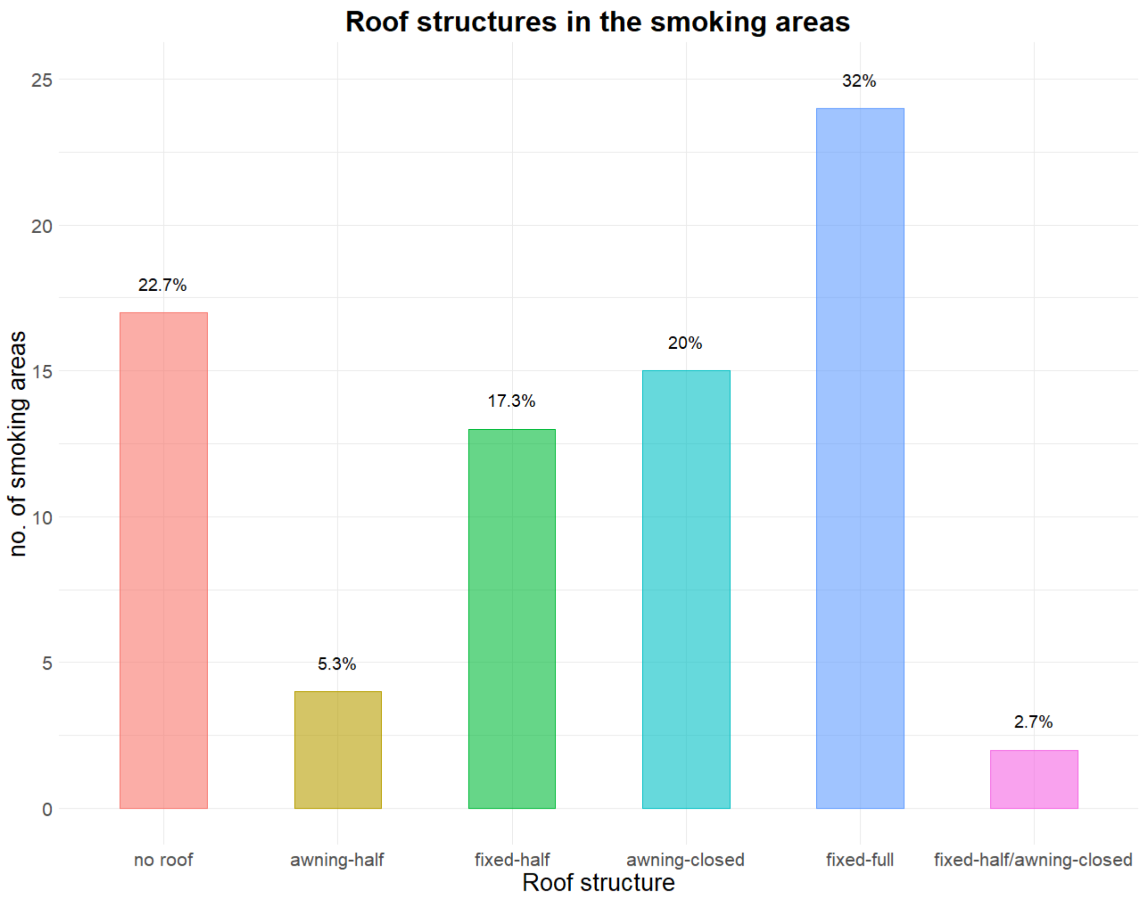


Figure 4.13: Smoking area roof structures.

Where a roof was present on the smoking area, the type of roof was noted and is graphed in figure 4.13. The legislation states that a roof is defined as fixed or movable and so awnings were noted in the position they were in at the time of sampling. Where an awning was present but not open the area was determined as having no roof. 32% (n= 24) of smoking areas were covered completely by a fixed roof while 20% (n= 15) were covered completely by an awning. 17.3% (n= 13) of smoking areas had a roof that covered half of the area while 5.3% (n= 4) had an awning pulled over half the area. 2.7% (n= 2) smoking areas were covered by a combination of half a fixed roof and an awning pulled over the other half. The remaining 22.7% (n= 17) of smoking areas had no roof.

Table 4.3: Did roof type effect mean $PM_{2.5}$.

Roof type	**Count (%)**	**Mean $PM_{2.5}$ ($\mu g/m^3$)**
Fixed (covering entire area)	24 (32%)	40.7
Fixed (half covering area)	13 (17%)	33.5
Awning (closed)*	17 (23%)	31.4
Awning (half open)	4 (5%)	35.1
No roof present	17 (23%)	16.3

*smoking areas that were covered by both an awning and a fixed roof (n= 2) were counted in this row.

In table 4.3 the mean $PM_{2.5}$ was found for each roof type to examine whether the type of roof on the smoking area affected the $PM_{2.5}$ concentrations. The results provide evidence that the presence of a roof, whether that be a fixed roof or movable awning, lead to higher concentrations than in uncovered smoking areas.

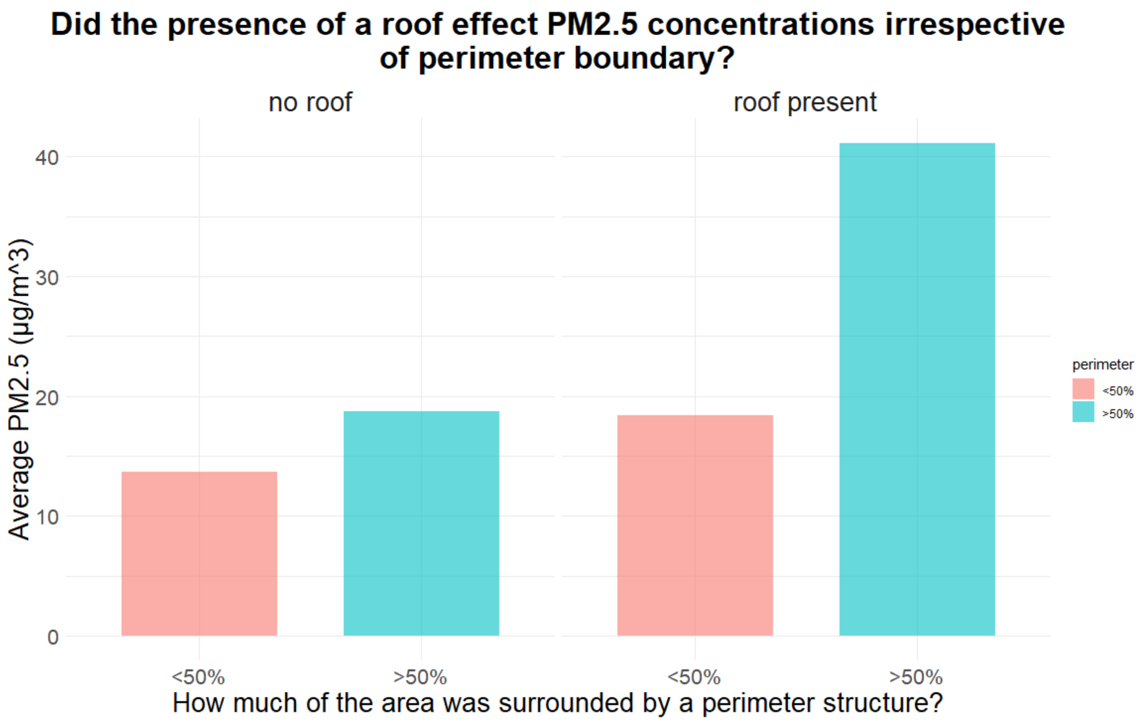


Figure 4.14: What effect did smoking area boundary and roof have on $PM_{2.5}$.

In figure 4.14 we can see that the mean $PM_{2.5}$ concentrations were higher in smoking areas with a roof irrespective of how much of that area was surrounded by a perimeter structure. Mean $PM_{2.5}$ in smoking areas with no roof was 13.7 µg/m^3 where the perimeter was not more than 50% of the area and 18.7 µg/m^3 where the perimeter was more than 50% of the area. Mean $PM_{2.5}$ in smoking areas with a roof was 18.4 µg/m^3 where the perimeter was not more than 50% of the area and 41.1 µg/m^3 in where the perimeter was more than 50% of the area.

4.1.4 Other sources of $PM_{2.5}$ within the smoking areas.

Due to the nature of the sampling technique (measuring only $PM_{2.5}$ as a marker for tobacco smoke), it was important that other possible sources of particulates be recorded to determine if they had any effect on the overall average. Overall average $PM_{2.5}$ in the smoking areas was 31.5 µg/m^3 and 11 µg/m^3 in non-smoking areas of the venues. Gas heaters were present in 61.3% of smoking areas visited. In smoking areas where gas heaters were present the average $PM_{2.5}$ was 34.3 µg/m^3. Smoking areas that were situated next to heavy traffic had an average $PM_{2.5}$ of 27.1 µg/m^3. Those with more than one other possible source of $PM_{2.5}$ e.g. a fire pit and cooking vents, had an average of 24.3 µg/m^3 while areas with no other sources of $PM_{2.5}$ had an average of 31.3 µg/m^3. From this data, and the limitation of the equipment to differentiate between sources, it cannot be concluded if other sources of $PM_{2.5}$ had an effect on the smoking related $PM_{2.5}$ within the smoking areas and it was ultimately beyond the scope of the project. Breakdown of this data can be found in appendix 7.7.12.

In order to overcome this limitation, if the project was to be revisited with an unlimited budget, recording of a tobacco specific marker such as nicotine would allow for differentiation between tobacco and non-tobacco sources. If $PM_{2.5}$ was measured alongside nicotine, the effect on measurements could be noted and controlled for.

4.1.5 Employee exposure to ETS

Table 4.4: Breakdown of employee presence within smoking areas.

No. of employees exposed	**% of smoking areas**
1-3 employees	64%
4-5 employees	16%
>5 employees	8%
0 employees present	12%
Time employee spent in the smoking area	**% of smoking areas**
<5 minutes	57.3%
5-15 minutes	14.7%
>15 minutes	16%
0 employees present	12%

Table 4.4 displays data that was recorded during the sampling period to assess the time spent within the smoking area by hospitality employees. There were 1-3 employees in 64% (n= 48) of smoking areas, 12% (n= 9) had no employees present. In 16% (n= 12), 4-5 employees were recorded while more than 5 employees were recorded in 8% (n= 6). In the majority of smoking areas, employees spent less than 5 minutes. They spent between 5 and 15 minutes in 14.7% of smoking areas and in 16%, they spent more than 15 minutes there during the sampling period.

Based on previous studies of hospitality staff exposure in Ireland (Goodman *et al.*, 2007) it was concluded that for this study personal measurements would not be taken. This was due to altered behaviours noticed by previous researchers, threats to job security of volunteers along with other ethical issues raised by employee unions. Personal monitoring would be valuable evidence to gather in future work, if attainable.

Table 4.5: Distribution of $PM_{2.5}$ concentrations recorded in smoking areas.

Quartiles (%)	$PM_{2.5}$ (µg/m³)	No. of smoking areas (%)	No. of smoking areas with employees present (%)
25%	<9.7	18 (24%)	15 (20%)
Median	<21.9	20 (27%)	19 (25%)
75%	<40.8	18 (24%)	15 (20%)
Maximum	<189.0	19 (25%)	17 (23%)

As table 4.5 illustrates, employees were noted working within 23% of smoking areas with average $PM_{2.5}$ concentrations in the upper quartile of greater than 40.8 µg/m³.

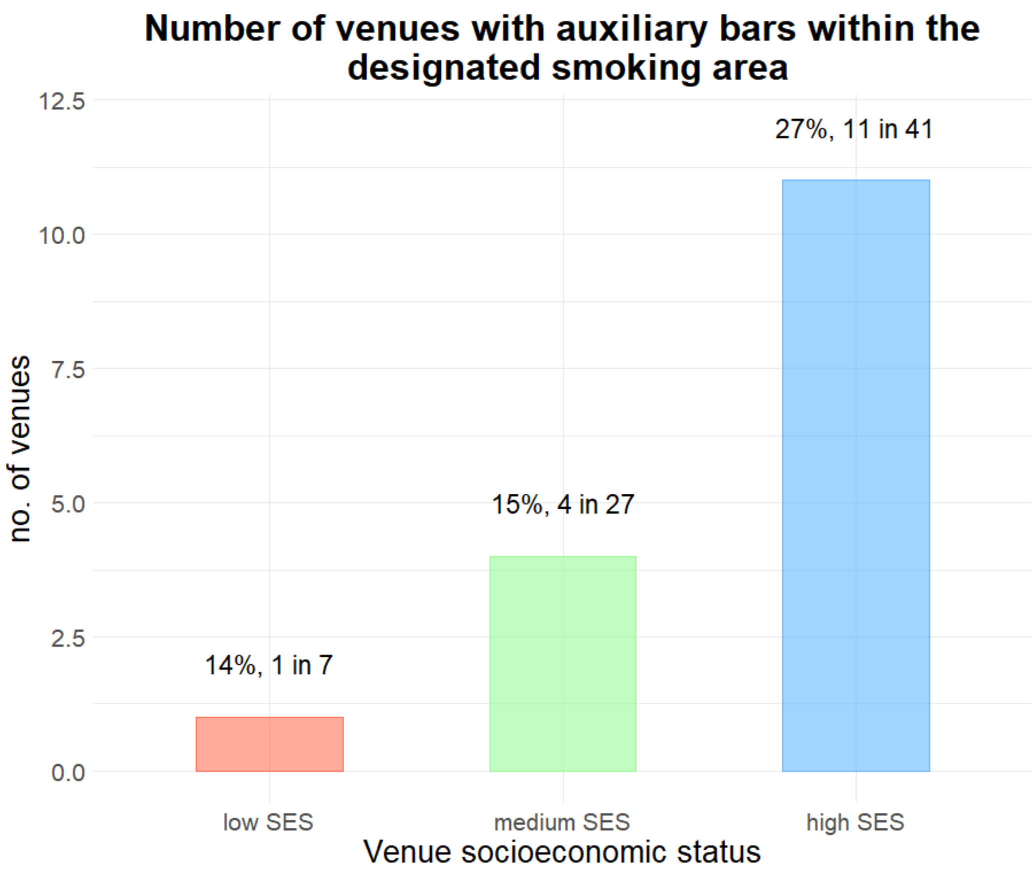


Figure 4.15: Smoking areas that contained a bar.

In 21.3% of smoking areas surveyed a permanent auxiliary bar was present. This could be categorised as an extension of the licensed premises as payment and service of alcohol was taking place where staff were present. In figure 4.15 there was 1 smoking area in a lower socioeconomic area with an auxiliary bar (14% of smoking areas in low socioeconomic areas), 4 smoking areas in medium socioeconomic areas had an auxiliary bar (15% of smoking areas in medium socioeconomic areas) and 11 smoking areas in high socioeconomic areas had an auxiliary bar, (27% of smoking areas in high socioeconomic areas).

An additional observation which increased the desirability to stay in the smoking areas was that 97.3% had comfortable seating for customers and 64% had a television screen on and/or music playing and/or games for customers.

Table 4.6: Employee exposure in smoking areas with an auxiliary bar.

Smoking area ID	**Average $PM_{2.5}$ (μg/m^3)**	**Employees at auxiliary bar**	**Employees in smoking area**	**Time spent in smoking area**
4	83.3	1	1-3	<5 minutes
6	7.3	0	1-3	<5 minutes
18	2	1	1-3	>15 minutes
30	1.8	1	1-3	>15 minutes
36	40.2	0	0	0
37	47.8	1	1-3	>15 minutes
43	18.3	0	1-3	<5 minutes
56	17	1	1-3	>15 minutes
58	55	3	4-5	>15 minutes
60	24	3	4-5	>15 minutes
70	39.4	1	1-3	>15 minutes
77	42.6	1	1-3	>15 minutes
83	15.2	0	1-3	<5 minutes
88	41	0	4-5	5-15 minutes
94	20.8	1	1-3	<5 minutes
99	50.5	1	4-5	>15 minutes

In smoking areas that contained an auxiliary bar, 69% had an employee stationed at that bar during the sampling period as shown in table 4.6. These auxiliary bar employees were exposed to average $PM_{2.5}$ concentrations ranging from 1.8 – 83.3 μg/m^3.

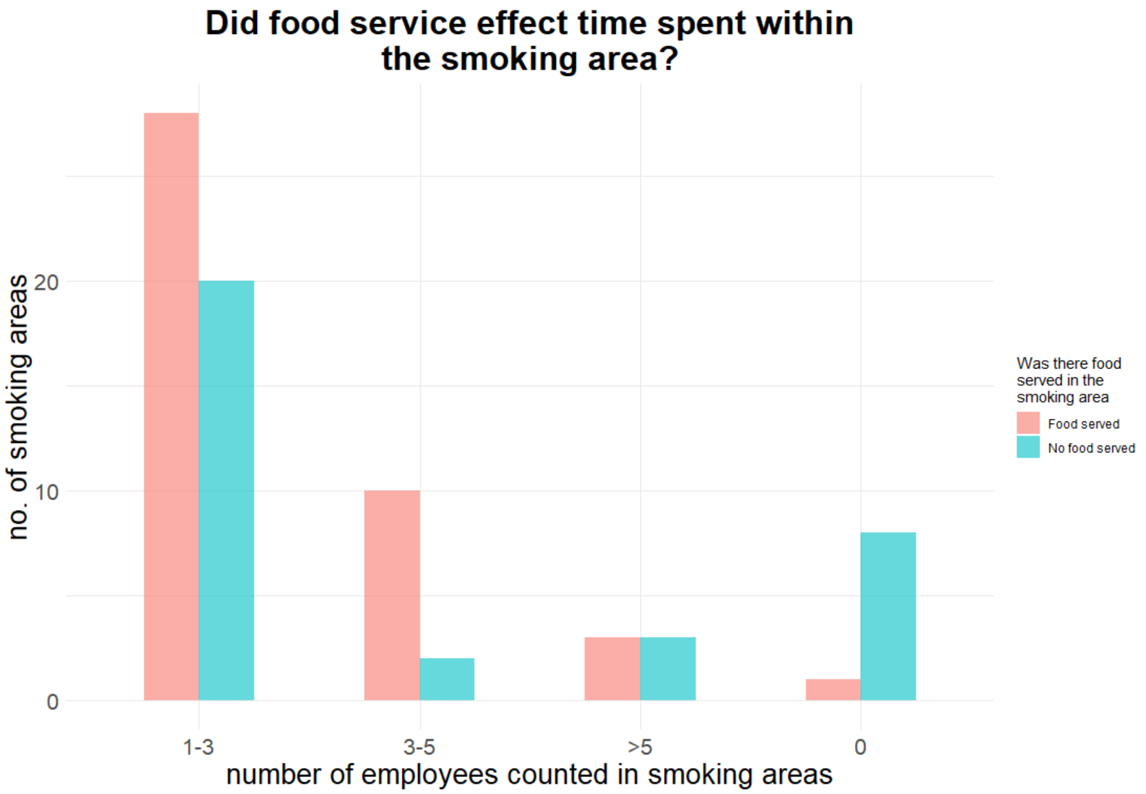


Figure 4.16: Did food service within smoking areas effect employee numbers present.

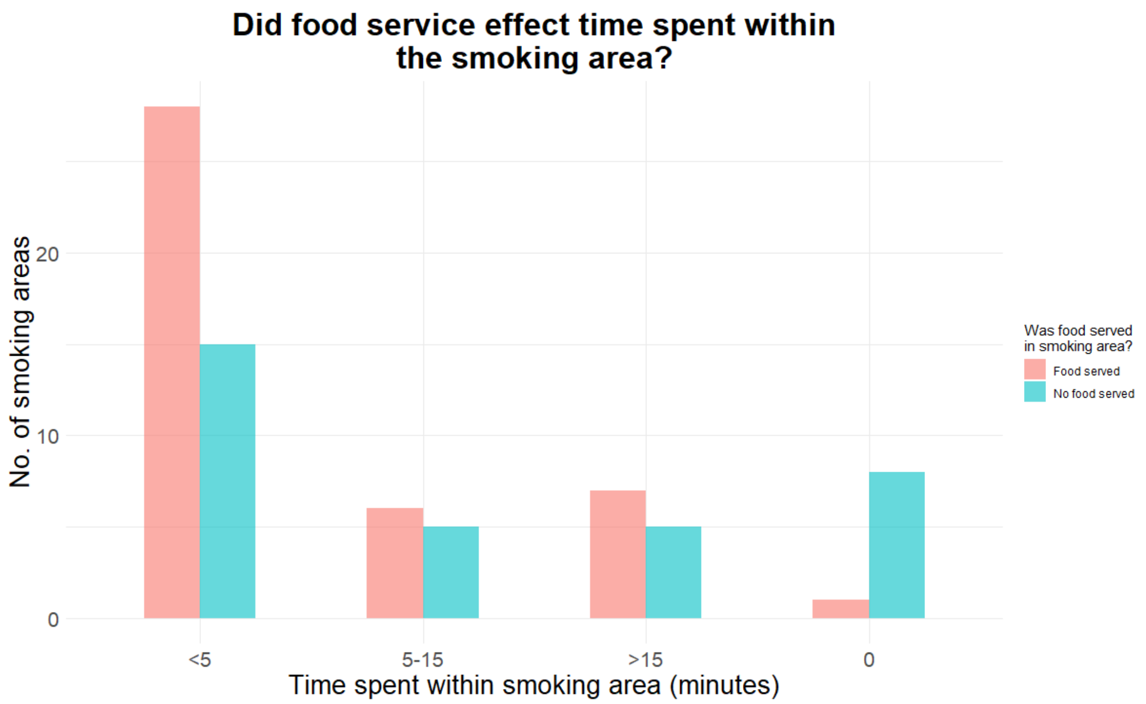


Figure 4.17: Did food service within smoking areas effect the time employees spent there.

When the data was filtered by venues that were providing food service within the smoking areas, the instance of employees within the smoking areas was higher as seen in figure 4.16. Figure 4.17 also shows that while time spent within the smoking areas was less than five minutes for the majority of employees, it was higher overall in smoking areas that operated food service within.

Table 4.7: Effect of public health guidelines on food service within smoking areas.

	No food served (no. of smoking areas)	**Food served (no. of smoking areas (%))**
Pre restrictions	3	9 (75%)
COVID restrictions	3	22 (88%)

The instance of food service within smoking areas was 75% from January to March 2020 and 88% from July to October 2020.

4.1.6 Air sampling results

Table 4.8: Mean $PM_{2.5}$ in non-smoking area of venue versus smoking area.

Indoor, non-smoking area of venues		**Designated smoking area of venues**	
Mean Indoor $PM_{2.5}$	11 µg/m^3	Mean smoking area $PM_{2.5}$	31.5 µg/m^3
Max mean indoor $PM_{2.5}$	52 µg/m^3	Max mean outdoor $PM_{2.5}$	189 µg/m^3
Min mean indoor $PM_{2.5}$	0.3 µg/m^3	Min mean outdoor $PM_{2.5}$	1.4 µg/m^3

Note: four venues had no indoor measurement due to COVID-19 restrictions on entering the venue.

$PM_{2.5}$ levels recorded both inside the non-smoking venue and within the smoking areas are compared in table 4.8. At each venue, recordings were taken inside the non-smoking portion of the venue in order to assess ambient $PM_{2.5}$ levels. When those indoor measurements were compared with those taken within the smoking areas, there was a statistical difference observed, $p < .001$.

Table 4.9: Ambient $PM_{2.5}$ concentrations recorded by EPA stations on sampling days.

Date	Smoking area ID	Average ambient $PM_{2.5}$ (µg/m^3) (Nearest station)	Indoor non-smoking area average $PM_{2.5}$ (µg/m^3)	Smoking area average $PM_{2.5}$ (µg/m^3)
03/05/19	SA84	8 – 11	6.6	13.2
12/06/19	SA58	8 – 11	6.0	55.3
24/07/19	SA94	8 – 11	25.8	20.8
30/08/19	SA29	8 – 11	19.0	15.8
28/09/19	SA48	8 – 11	5.3	43.5
15/10/19	SA21	8 – 11	46.3	24.0
02/11/19	SA36	8 – 11	9.4	40.2
13/12/19	SA14	8 – 11	3.1	5.8
22/01/20	SA91	No data	10.8	40.8
14/02/20	SA60	10.8 (Marino)	7.6	24.0
06/03/20	SA13	6.8 (Rathmines)	11.0	48.2
26/07/20	SA23	2.5 (Phoenix Park)	3.5	1.4
08/08/20	SA99	4.9 (Lord Edward St)	6.7	50.5
18/09/20	SA01	7.4 (Ballyfermot)	1.2	16.7
07/10/20	SA57	5.3 (Rathmines)	-- (COVID-19)	13.7

Data from EPA monitoring sites located across Dublin in 2019 had annual mean $PM_{2.5}$ concentrations ranging from 8 – 11 µg/m^3 (EPA, 2019a). These mean concentrations are reflective of the ambient background measurements taken as part of this project in Spring 2019 (see appendix 7.2). Table 4.9 is a subset of smoking areas sampled in 2020 alongside the ambient $PM_{2.5}$ concentrations for that day as reported by the EPA via airquality.ie/calendar. Daily data for 2019 was unavailable on the calendar and so, the average reported by the EPA is included for reference.

Table 4.10: Smoking area concentrations categorised by applying the EPA AQIH

Four bands of air quality	Smoking areas %	Index (1-10)	Smoking areas %	Count
Good	69.3%	1	24%	18
		2	26.6%	20
		3	18.7%	14
Fair	17.3%	4	6.7%	5
		5	6.7%	5
		6	4%	3
Poor	2.7%	7	1.3%	1
		8	1.3%	1
		9	--	--
Very poor	10.7%	10	10.7%	8

If we refer back to table 2.2 discussed in section *2.1.3 Particulate matter $_{2.5}$*, with the results of the sampling we can begin to see how the smoking areas sampled would be classified if these concentrations were recorded as ambient measurements in Dublin which is displayed in table 4.10. Using the four bands of air quality, the smoking areas were categorised.

4.1.7 A closer look at smokers recorded in the smoking areas

There was no relationship (correlation = 0.24) found between the average number of smokers within a smoking area and the average $PM_{2.5}$ recorded in that area (see appendix 7.7.16). While the overall averages show no correlation, an in depth look at individual smoking area $PM_{2.5}$ spikes in relation to the number of smokers recorded each 15 minutes (highlighted in red) provide a more accurate representation of the effects. A selection of 10 smoking areas, five compliant and five non-compliant, are displayed in the following pages.

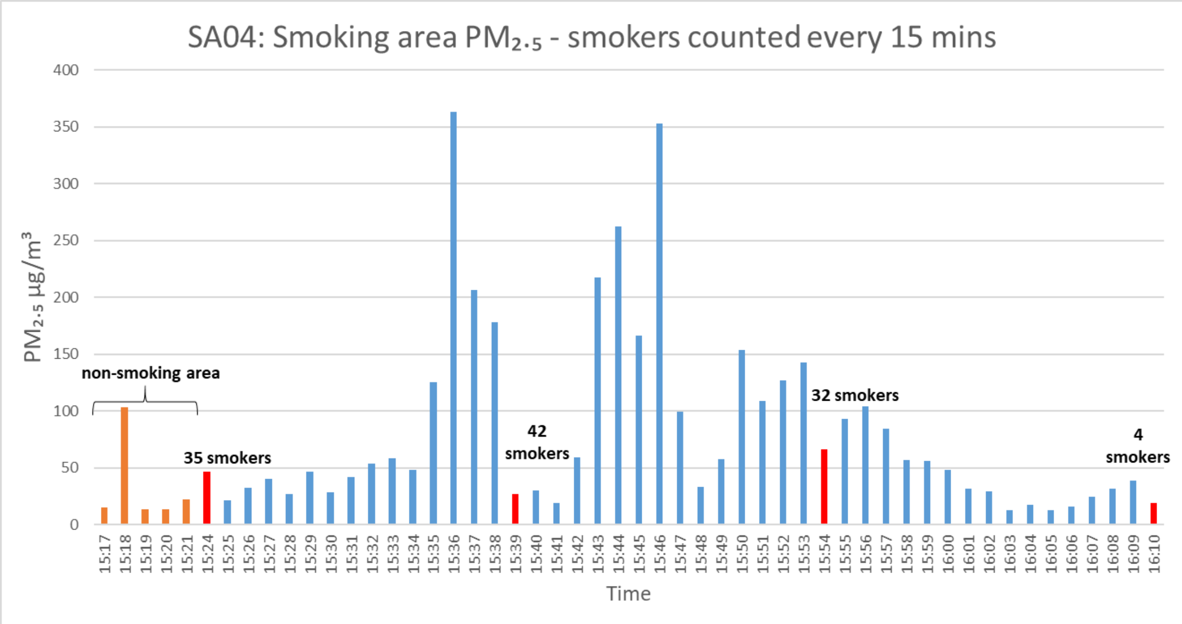


Figure 4.18: SA04

Figure 4.18 is an example of a non-complaint suburban smoking area $PM_{2.5}$ levels over the course of a 45-minute period. During this period, 1-3 employees were recorded spending less than 5 minutes within the smoking area. A count of smokers was taken every 15 minutes, highlighted in red. The $PM_{2.5}$ measurements for the indoor non-smoking area of the venue is included at the beginning of the graph highlighted in orange. The average $PM_{2.5}$ for the indoor non-smoking area was 33.6 µg/m^3 while the smoking area had an average of 83.3 µg/m^3. This venue was located within a medium socioeconomic area. The smoking area included an auxiliary bar with one employee stationed for the entire sampling period. Food was served within the area where there was an average of 45 customers as well as children present.

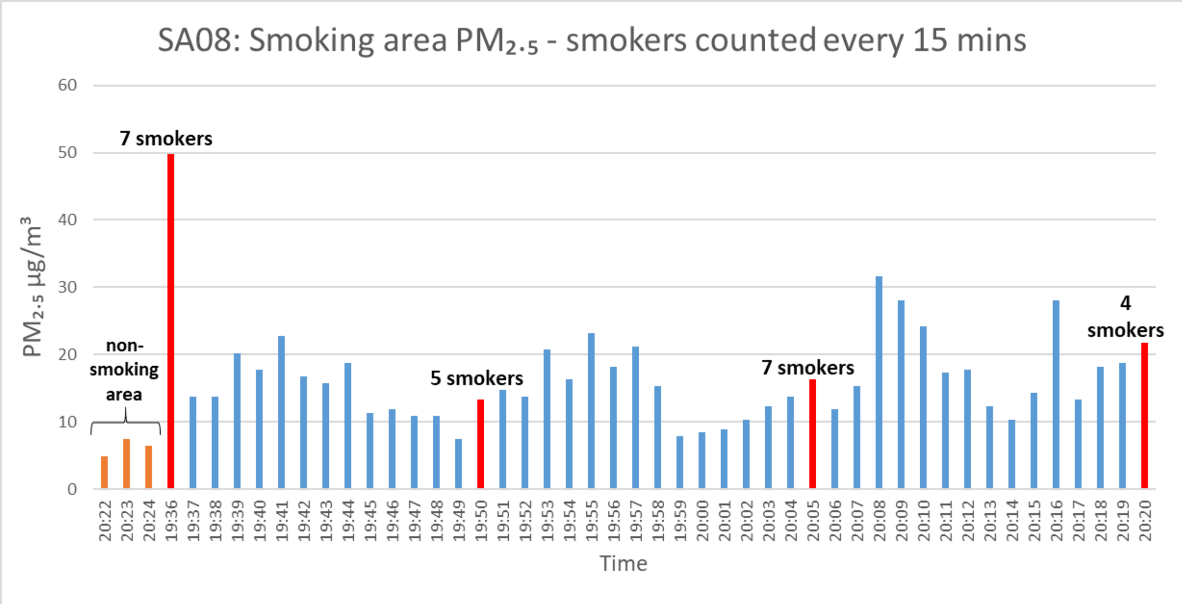


Figure 4.19: SA08

The smoking area displayed in figure 4.19 was in a venue located in a high socioeconomic area. The smoking area was compliant with just half of the area covered with a roof and no perimeter boundaries. The average $PM_{2.5}$ for the indoor non-smoking area was 6.2 $\mu g/m^3$ while the average within the smoking area was 16.9 $\mu g/m^3$. 1-3 employees were recorded spending less than 5 minutes within the smoking area that night.

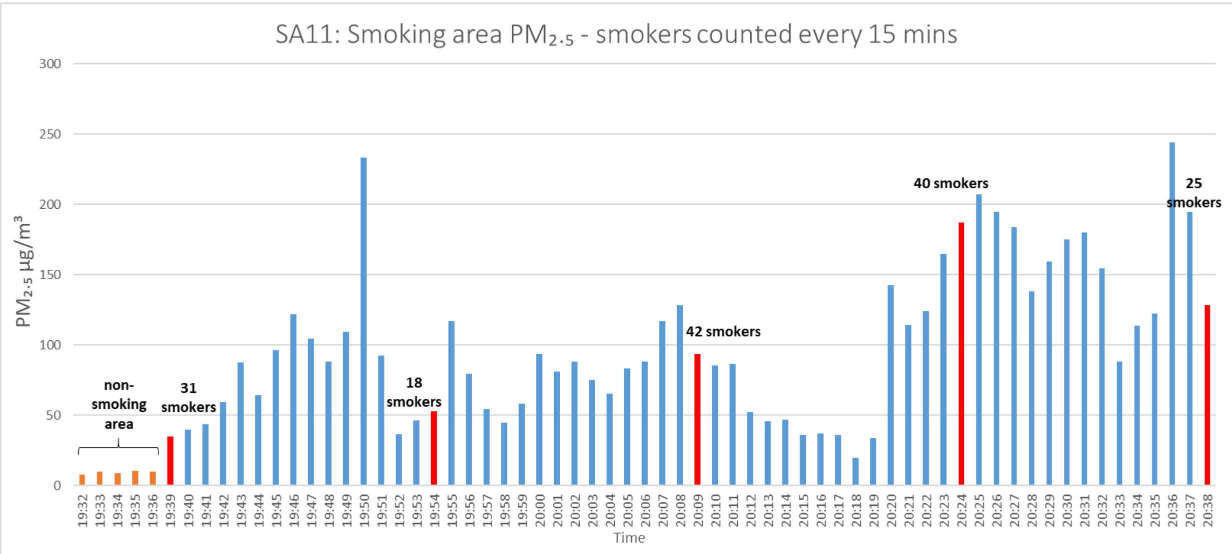


Figure 4.20: SA11

Figure 4.20 was a non-compliant city centre smoking area that was sampled for 1 hour and had an average $PM_{2.5}$ 101.4 µg/m^3. The maximum recording was 244 µg/m^3 with a minimum of 19.7 µg/m^3. This venue was located in a high socioeconomic area and was fully enclosed by an awning and a permanent wall perimeter boundary. More than 5 employees were recorded spending from 5 to 15 minutes within the smoking area during this sampling time. The indoor non-smoking area had an average $PM_{2.5}$ of 9.5 µg/m^3.

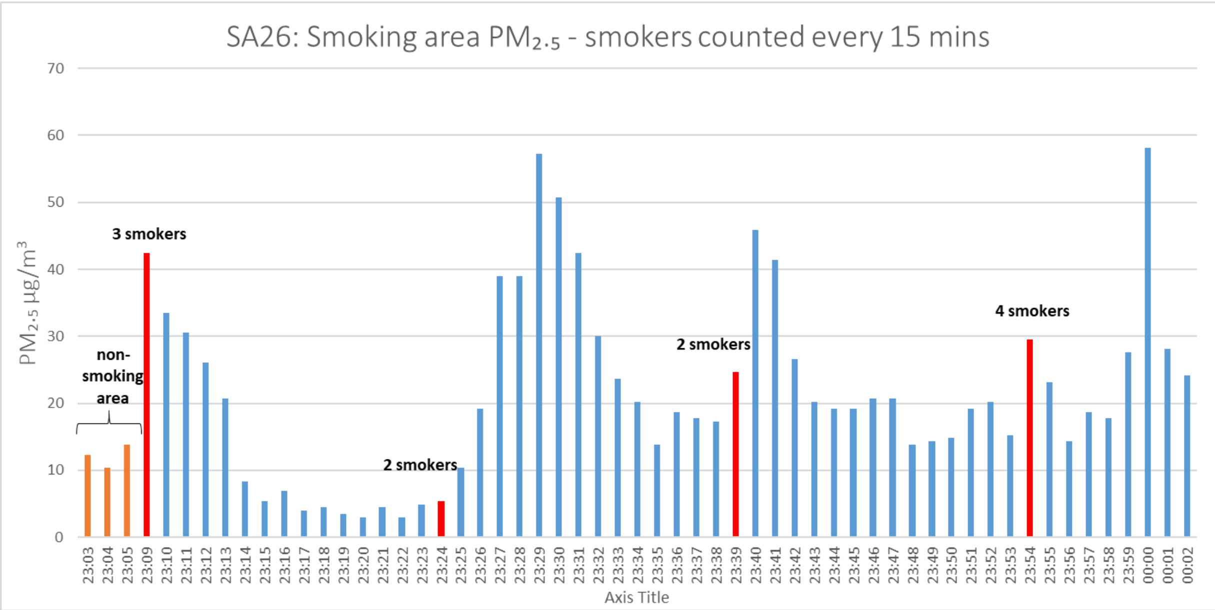


Figure 4.21: SA26

SA26 was a non-compliant suburban smoking area located in venue in a high socioeconomic area sampled on a Friday night. The area had a sign present which stated that smoking was not allowed when the roof awning was closed, this however was not being enforced during the visit. 1-3 employees were recorded spending between 5 and 15 minutes within the smoking area whilst sampling took place. The smoking area was surrounded by 4 permanent walls, making the area essentially an indoor room. Inside the non-smoking area the average $PM_{2.5}$ was 12.2 µg/m^3, while the average within the smoking area was 21.9 µg/m^3 with a maximum recording of 58.2 µg/m^3, minimum of 3 µg/m^3.

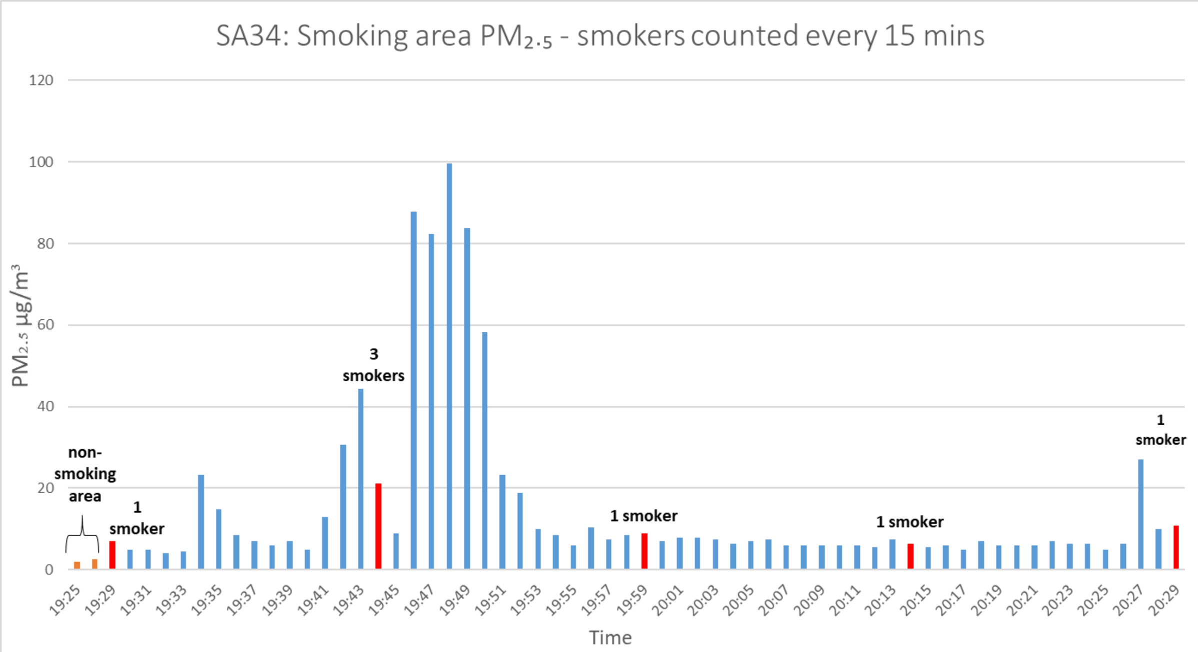


Figure 4.22: SA34

Figure 4.22 illustrates the measurements for another suburban non-compliant venue sampled on a very calm, warm Tuesday night in July 2019. This venue was located in a high socioeconomic area. This smoking area was a room within the venue with two openings in one wall presumably where there once was a window pane. The average $PM_{2.5}$ inside the non-smoking area of the venue was 2.2 µg/m^3 while within the smoking area it averaged at 15.5 µg/m^3. While the particulate levels remained below 10 µg/m^3 for the majority of the time with the presence of just 1 smoker, a significant spike occurred once two more smokers were present reaching a maximum reading of 100 µg/m^3. 1-3 employees were recorded spending less than 5 minutes within the smoking area.

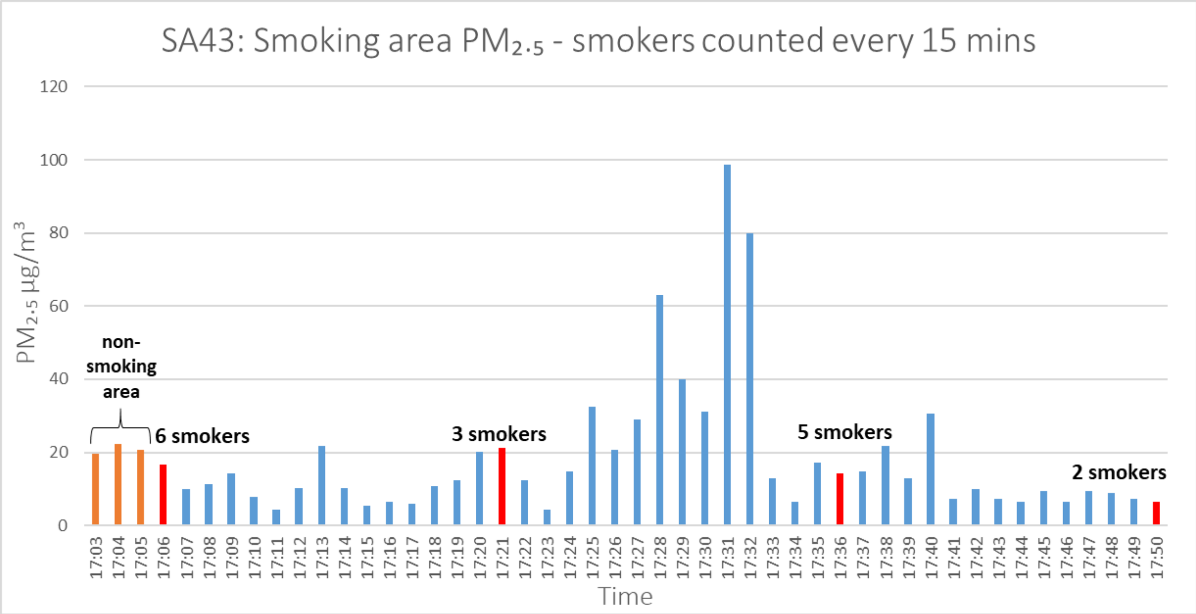


Figure 4.23: SA43

The compliant smoking area in figure 4.23 had an average $PM_{2.5}$ of 18.3 µg/m^3. The venue was located in a suburban high socioeconomic area. 1-3 employees were recorded spending less than 5 minutes within the smoking area during the 45-minute sampling period. While there was an auxiliary bar present, no employees were stationed there during the sampling period. The maximum recording was 99 µg/m^3 and minimum of 4 µg/m^3. The indoor non-smoking area had a higher average $PM_{2.5}$ at 20.9 µg/m^3. Sampling was done on a cold, moderately windy February afternoon.

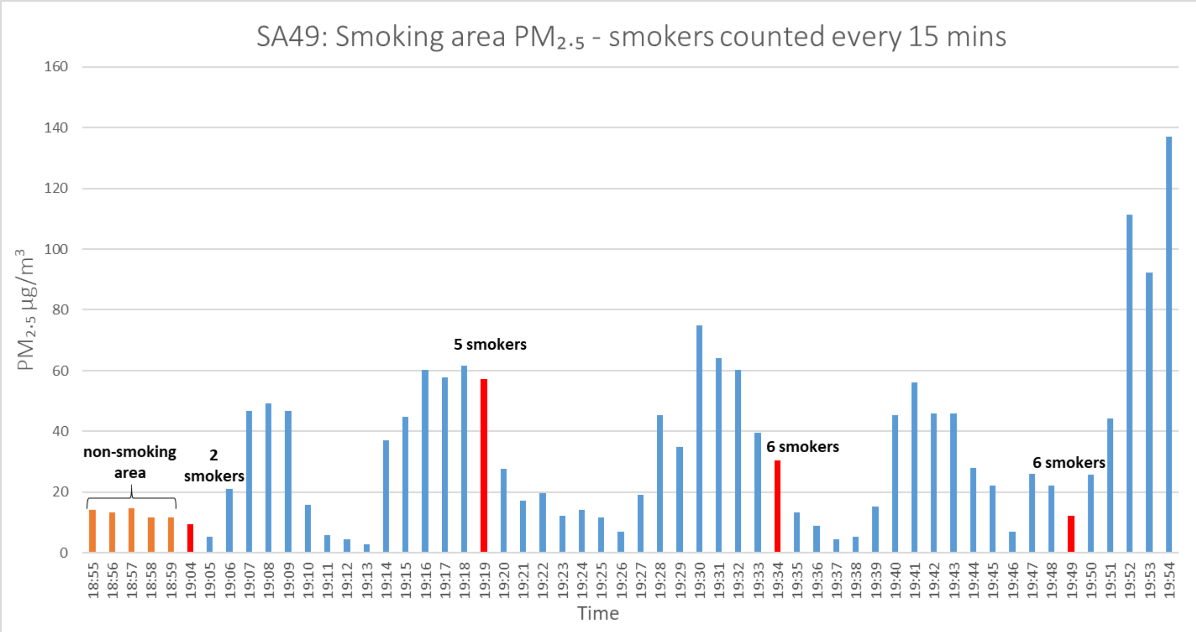


Figure 4.24: SA49

An average $PM_{2.5}$ of 34.8 µg/m^3 was recorded in the compliant suburban smoking area in figure 4.24. This area was covered by a roof however the perimeter boundary was less than 50% of that area. There were 1-3 employees recorded spending more than 15 minutes of the sampling period within this smoking area taking orders and cleaning the area. A maximum reading of 137 µg/m^3 and a minimum of 3 µg/m^3 was recorded while the indoor average was 13.7 µg/m^3. Sampling took place on a moderately windy Saturday night. This venue had a medium socioeconomic status.

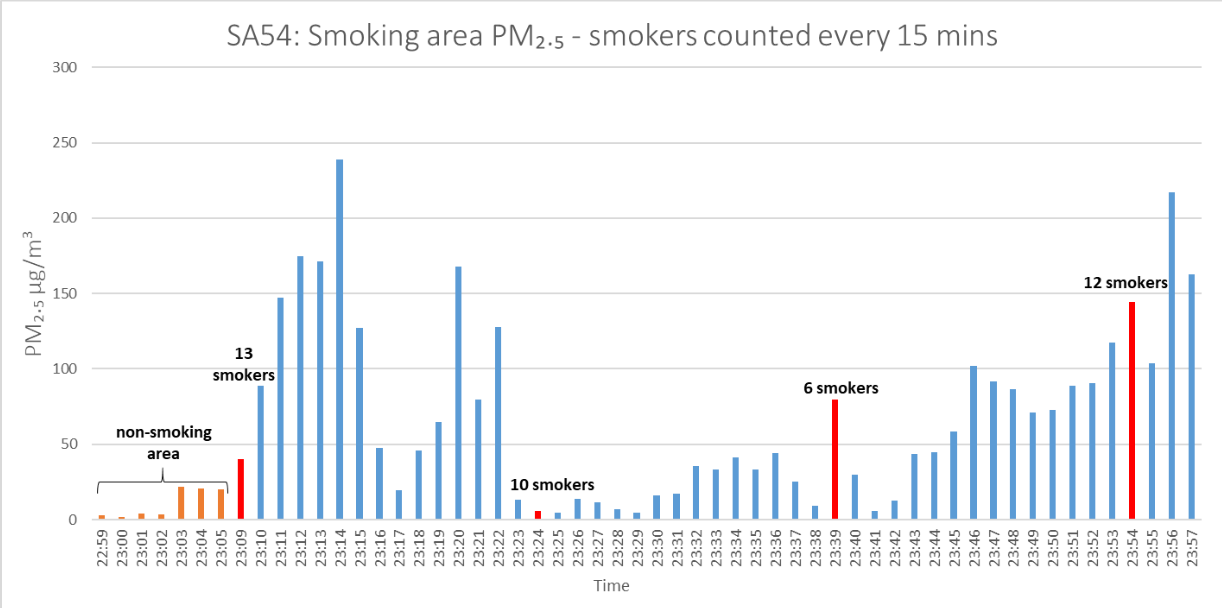


Figure 4.25: SA54

SA54 displayed in figure 4.25 was a non-compliant suburban smoking area covered by a fixed roof and surrounded by both full height and half height permanent walls. The indoor non-smoking area had an average $PM_{2.5}$ of 10.6 µg/m^3 while the smoking area had an average $PM_{2.5}$ of 71 µg/m^3. There were 4-5 employees noted spending less than 5 minutes within the smoking area. This venue, which was located in a medium socioeconomic area, was sampled on a wet and moderately windy Saturday night.

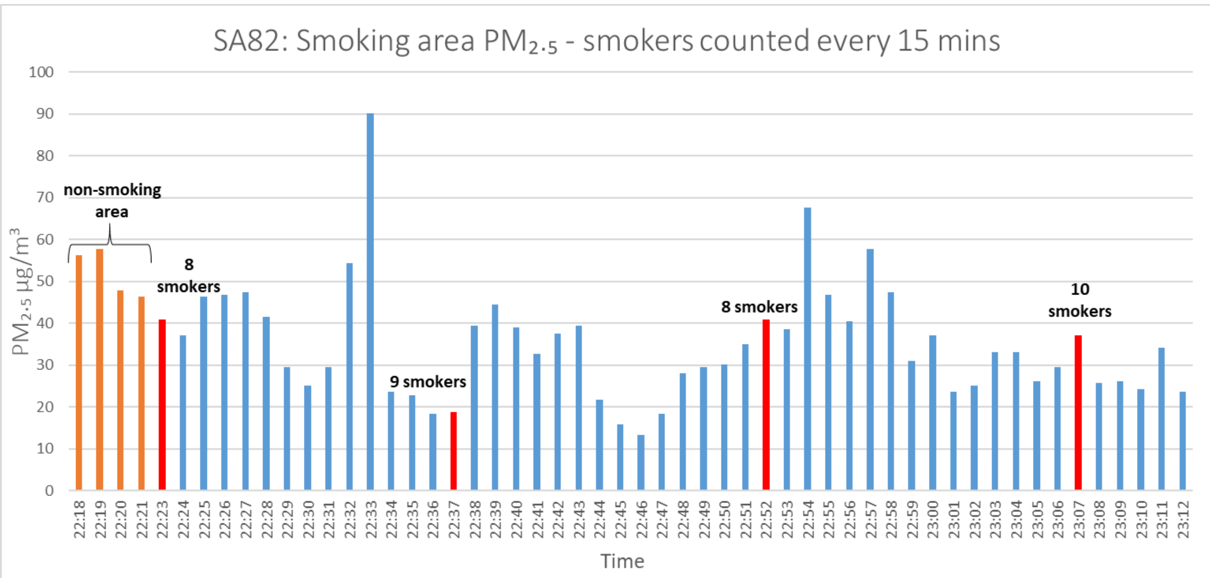


Figure 4.26: SA82

The suburban smoking area in figure 4.26 was compliant with a roof and a glass perimeter of not more than 50%. There was an average of 31 customers present that night within the smoking area. The venue was located in a medium socioeconomic area. The average $PM_{2.5}$ was 34.9 µg/m^3 in the smoking area. The highest measurement recorded was 90 µg/m^3 while the lowest was 13 µg/m^3. The indoor, non-smoking area of this venue had higher $PM_{2.5}$ measurements with an average of 52 µg/m^3. This could be due to the fact the door remained open to the smoking area along with two wide open windows. This smoking area was well staffed with more than 5 employees recorded spending more than 15 minutes there.

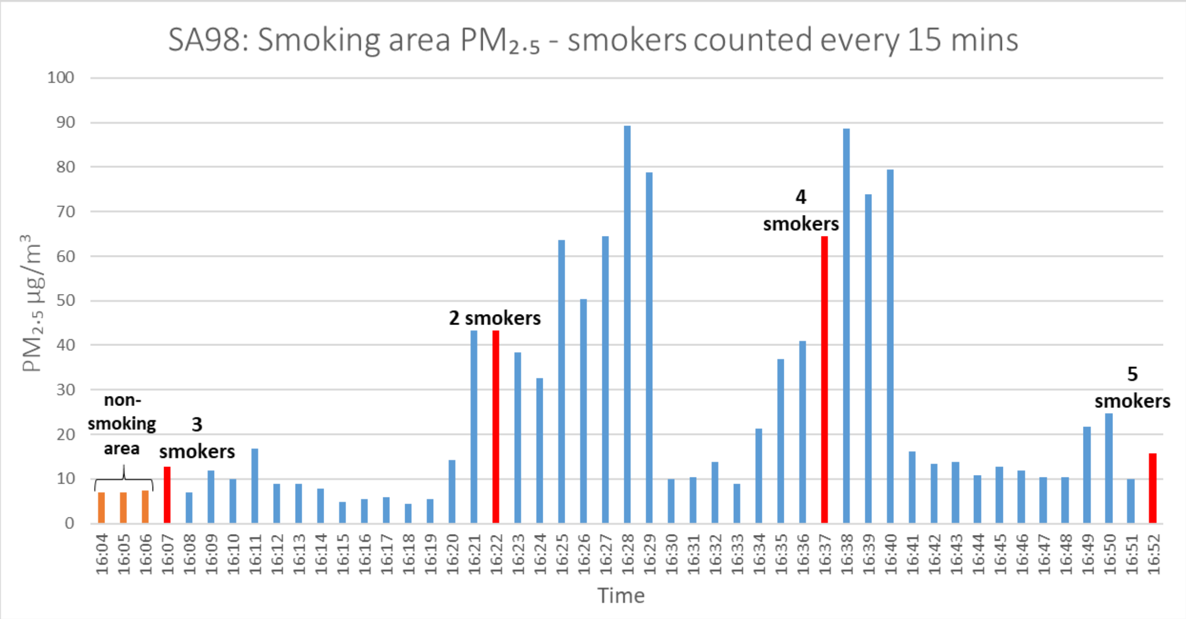


Figure 4.27: SA98

The compliant city centre smoking area illustrated in figure 4.27 was sampled on a very windy March afternoon. The venue was in a medium socioeconomic area. The indoor non-smoking area had an average $PM_{2.5}$ of 7.1 µg/m^3. The smoking area average was 27.1 µg/m^3 with a maximum $PM_{2.5}$ of 89 µg/m^3 and a minimum of 4 µg/m^3. This smoking area had no roof with 2 glass screens and one permanent wall enclosing it. 1-3 employees were recorded spending less than 5 minutes within the smoking area whilst taking food orders and clearing tables.

4.1.8 Seasonal effects

No statistical differences were observed when average $PM_{2.5}$ results for each smoking area were categorised by season. The means were, Spring = 26.6 µg/m^3, Summer = 30.2 µg/m^3, Autumn = 36.9 µg/m^3, Winter = 22.1 µg/m^3 (see appendix 7.7.17).

If this study was repeated outside Dublin it would be expected that $PM_{2.5}$ concentrations would vary, particularly due to the Smoky (bituminous) Coal Ban in place in Dublin since 1990. An extension of this ban was extended to 13 new areas from September 1st 2020 to include all towns with populations over 10,000 (Irish Statute Book, 2020). Measurements taken prior to this ban would be influenced by other air pollutants such as smoky coal burning.

4.1.9 Other variables

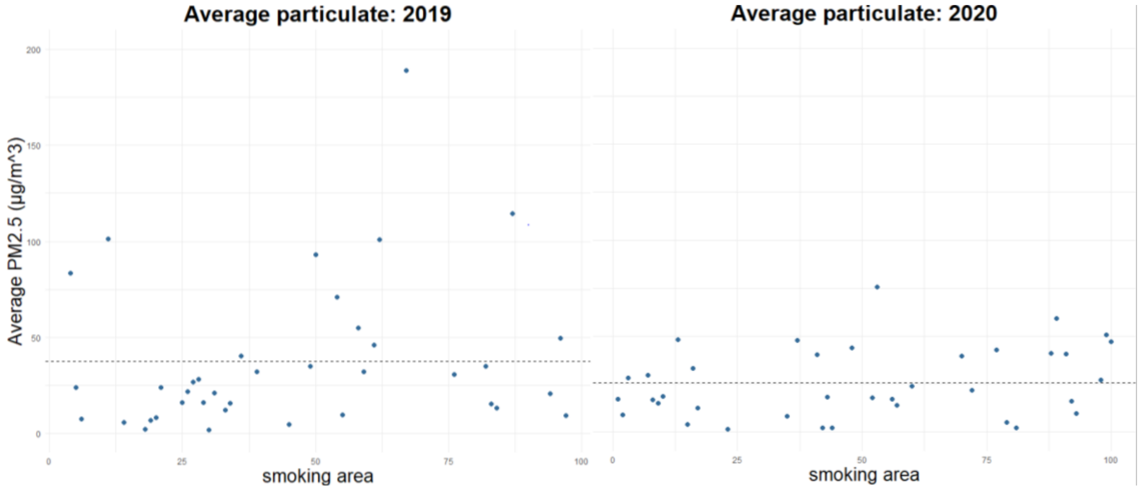


Figure 4.28: Observed changes from 2019 to 2020.

Of the 75 smoking areas sampled, 38 were visited in 2019 and 37 in 2020. Figure 4.28 shows that overall, 2019 had higher levels of $PM_{2.5}$ recorded as shown by the mean lines, 37.3 µg/m^3, while the mean $PM_{2.5}$ in 2020 was 25.6 µg/m^3 (p = .1). A probable cause of this decrease would be COVID-19 restrictions effecting the hospitality industry by reducing the number of customers to adhere to social distancing. Another possible reason for the decrease could have been due to health advice directed at smokers to quit smoking throughout the pandemic.

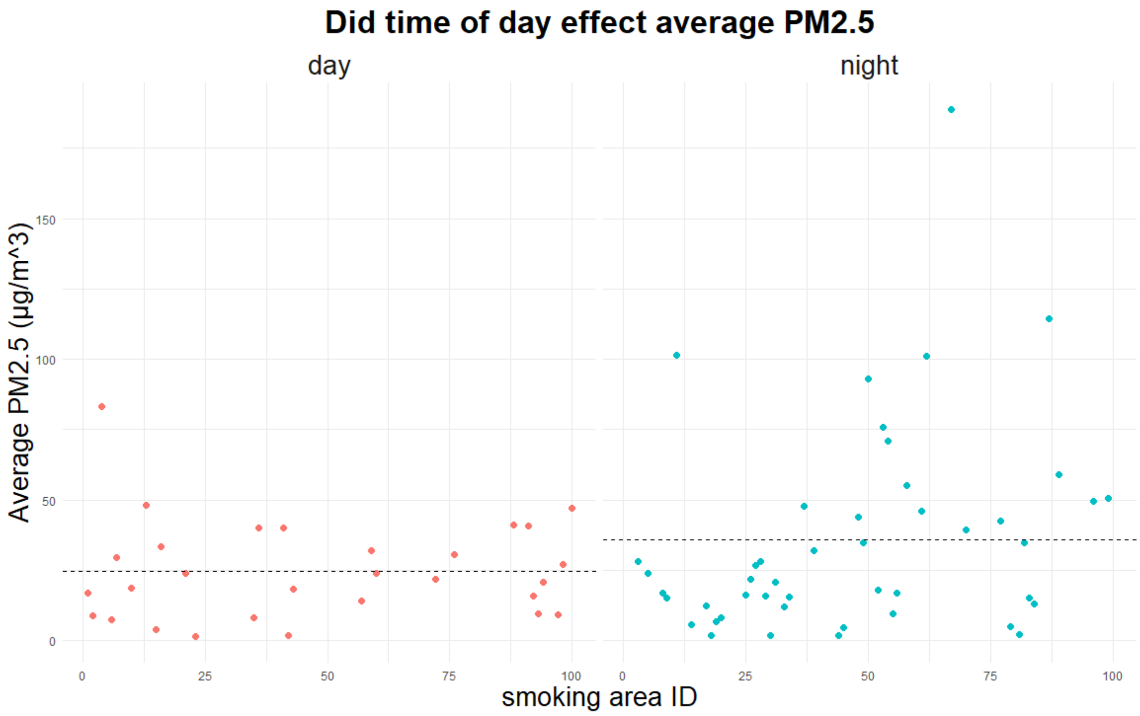


Figure 4.29: Did time of day effect average $PM_{2.5}$.

Figure 4.29 depicts the results of all smoking areas sampled, 29 smoking areas were sampled during the day, while 46 were sampled at night. Sampling times were categorised into day (12:00 – 18:00) and night time (18:00 – close). As expected, smoking areas sampled at night saw higher average $PM_{2.5}$ levels, day = 24.8 μg/m^3, night = 35.8 μg/m^3. This result was also analysed and was not deemed statistically significant with a p-value of .087.

Table 4.11: Smoking data by time of day.

Time of day	Average smokers	Max smokers	Min smokers
Day (12:00-18:00)	4.4	28	1
Night (18:00-close)	6	39	0

4.2 Health assessment results

Ten volunteers took part in spirometry tests and carbon monoxide tests before during and after exposure to environmental tobacco smoke (ETS), in order to investigate whether there were immediate respiratory effects. This was done to mimic employee exposure during a shift within the hospitality industry where their workplace has a designated smoking area. All volunteers were healthy, non-smokers with no respiratory issues. The spirometry tests measured FEV1, FVC and PEF. The forced expiratory volume in one second (FEV1) is the amount of air exhaled by force in one second while forced vital capacity (FVC) is the total volume of air exhaled in one breath. Peak expiratory flow (PEF) is the maximum flow in litres/minute exhaled from the lungs. Peak flow was measured both within the spirometry test (PEF) and manually (PF). The results of these tests are displayed in the tables below.

Table 4.12: Spirometry test results

Test	**Pre exposure (avg % predicted)**	**Post exposure (avg % predicted)**	**p-value**
FEV1	99.8	99.4	0.34
FVC	99.5	97.2	0.15
PEF	109.9	112.5	0.20
Test	**Pre exposure (mean)**	**Post exposure (mean)**	**p-value**
CO (avg)	1.3	1	0.17

Table 4.13: Manual peak flow results

Test	Pre exposure (avg % predicted)	During exposure (avg % predicted)	p-value
PF	110.5	106.8	0.051
	Pre exposure	**Post exposure**	**p-value**
PF	110.5	108.8	0.057

The results from the health assessments displayed in tables 4.12 and 4.13 provided some insight into the immediate effect of ETS exposure on employee health. An effect on FEV1 was noted in four volunteers who decreased post exposure, three had improved whilst three remained the same. Ultimately, these results are not suggestive of any effect on the volunteers FEV1. For FVC, seven volunteers had decreased levels post exposure while three had improved. These results are suggestive (p = .146) of an effect of ETS exposure on FVC and had the sample size been bigger, more definitive results may have been seen.

The results of the carbon monoxide test were lower than what was expected, however, it is unusual to see values above 6ppm in non-smokers. Levels below 6 are deemed normal levels and none of the volunteers measured higher than 6. While some did increase after exposure, it cannot be taken as a significant result as other volunteers levels decreased after exposure.

The manual peak flow results showed a suggestive effect between pre-exposure and during exposure (p = .051) and pre exposure and post exposure (p = .057). In six volunteers their PF either decreased during exposure and recovered or decreased entirely as a result of exposure. Three volunteers had no change while HA09 had a marginal improvement. Age, height, weight or sex does not affect these results as they are the % predicted when these variables are included. See appendix 7.7.20 for all health data and statistical tests.

Table 4.14: Health data with observed % changes

Volunteer	Test time	Average $PM_{2.5}$	FEV1 value	% Predicted	FVC value	% Predicted	PEF value	% Predicted	CO PPM	Peak flow	% Prediction	% Change
HA01	pre exposure	117.3	3.57	102	4.35	109	464	103	1	490	110	
SA49	during	34.8								490	110	**0%**
	post exposure	5.4	3.48	100	3.89	97	460	102	0	490	110	**0%**
			-3%	**-2%**	**-11%**	**-11%**	**-1%**	**-1%**	**-100%**			**0%**
HA02	pre exposure	7.9	3.28	96	3.65	94	443	100	0	510	120	
SA31	during	21.0								420	99	**-18%**
	post exposure	5.9	3.37	100	3.72	96	530	121	0	500	118	**19%**
			3%	**4%**	**2%**	**2%**	**20%**	**21%**	**0%**			**-2%**
HA03	pre exposure	3.5	3.54	91	4.45	91	666	121	2	680	111	
SA55	during	9.7								670	109	**-1%**
	post exposure	3.0	3.45	89	4.22	86	605	110	0	650	106	**-3%**
			-3%	**-2%**	**-5%**	**-5%**	**-9%**	**-9%**	**-100%**			**-4%**
HA04	pre exposure	2.0	2.36	121	2.73	117	392	119	2	370	107	
SA21	during	24.1								340	98	**-8%**
	post exposure	1.0	2.36	121	2.75	118	388	117	1	370	107	**9%**
			0%	**0%**	**1%**	**1%**	**-1%**	**-2%**	**-50%**			**0%**
HA05	pre exposure	80.0	4.2	90	4.68	84	559	90	1	570	97	
SA39	during	31.9								550	94	**-4%**
	post exposure	55.0	4.13	89	4.6	83	550	89	2	570	97	**4%**
			-2%	**-1%**	**-2%**	**-1%**	**-2%**	**-1%**	**100%**			**0%**

Volunteer	Test time	Average $PM_{2.5}$	FEV1 value	% Predicted	FVC value	% Predicted	PEF value	% Predicted	CO PPM	Peak flow	% Prediction	% Change
HA06	pre	1.5	2.64	122	3.22	126	492	144	3	500	136	
SA18	during	2.0								500	136	**0%**
	post	2.0	2.64	122	3.02	118	497	144	2	500	136	**0%**
			0%	**0%**	**-6%**	**-6%**	**1%**	**0%**	**-33%**			**0%**
HA07	pre	9.0	4.5	102	5.84	111	624	104	2	650	106	
SA30	during	1.8								640	104	**-2%**
	post	8.0	4.54	103	5.63	107	640	107	2	610	99	**-5%**
			1%	**1%**	**-4%**	**-4%**	**3%**	**3%**	**0%**			**-6%**
HA08	pre	2	2.65	81	2.97	79	479	111	1	460	110	
SA14	during	5.8								460	110	**0%**
	post	2.5	2.45	74	2.79	74	483	122	1	440	105	**-4%**
			-8%	**-9%**	**-6%**	**-6%**	**1%**	**10%**	**0%**			**-4%**
HA09	pre	2.5	4.22	95	4.32	82	635	106	0	700	114	
SA79	during	5.1								700	114	**0%**
	post	3	4.35	98	4.93	94	707	118	1	710	116	**1%**
			3%	**3%**	**14%**	**15%**	**11%**	**11%**	**100%**			**1%**
HA10	pre	2.5	4.58	98	5.64	102	627	101	1	600	94	
SA79	during	5.1								600	94	**0%**
	post	3	4.54	98	5.51	99	590	95	1	600	94	**0%**
			-1%	**0%**	**-2%**	**-3%**	**-6%**	**-6%**	**0%**			**0%**

Table 4.14 illustrates the percentage changes observed between measurements taken before during and after exposure to environmental tobacco smoke.

Chapter five: Discussion

5. Introduction

This study was carried out to determine the current state of compliance with the Public Health (Tobacco) (Amendment) Act 2004 of designated smoking areas in hospitality venues across Dublin. With the aim of assessing current employee exposure within the industry, the study set out to gather $PM_{2.5}$ concentrations, observe employee presence and the contextual variables of the smoking areas. This chapter will discuss the findings and summarise the current state of compliance with the Public Health (Tobacco) Acts in order to enact change that will protect employee health as well as assisting Environmental Health Officers in their roles of tobacco control. The results confirm that smoking areas were non-compliant in the majority of venues visited. These smoking areas had higher $PM_{2.5}$ concentrations than those that were compliant with section 47 of the 2004 Act. Employees were noted spending time during their shifts within the smoking areas of 88% of venues visited. An auxiliary bar was found in 21.3% of smoking areas, an extension of the licensed premises into the smoking area, further increasing the risk of adverse health effects on employees.

5.1 Smoking area compliance

A non-compliant smoking area is defined by section 16 of the Public Health (Tobacco) Act 2004, amendment of section 47 of the Principle Act: "*a place or premises, or a part of a place or premises, that is wholly uncovered by any roof, whether fixed or movable*", "*an outdoor part of a place or premises covered by a fixed or movable roof, provided that not more than 50 per cent of the perimeter of that part is surrounded by one or more walls or similar structures (inclusive of windows, door, gates or other means of access to or egress from that part)*". 60% of the smoking areas visited across Dublin were deemed non-compliant. Evidence of this widespread non-compliance was not observed when the fines for breaches of section 47 were investigated. Five fines were served in Dublin between 2015 and 2020, while 15 were served on venues in Donegal and 10 in Galway over the same time period (HSE, 2019b). The number of fines given in Dublin was not found to be a true representation of the volume of non-compliances found in this study which spanned over an 18-month period. This is in no way a reflection on the hard work of Environmental Health Officers as food related inspections take priority due to the risk of an immediate danger to public health, as well as the sheer volume of food businesses in the Capital City compared to other counties. However, there is no doubt that the issue of tobacco control within the sector must be addressed in order to protect the health of hospitality employees who do not choose to work in environments with high levels of secondhand smoke. Prioritisation of tobacco within the operational plan along with amendments to legislation are needed to allow for enforcement to accelerate.

When the venues socioeconomic status was controlled for, those located in lower socioeconomic areas had the highest mean $PM_{2.5}$ concentrations with 86% of the smoking areas non-compliant with legislation. This result does reflect the points discussed by Laaksonen, et al., in their 2005 paper, education level may be considered essential for making health behaviour choices concerning smoking. The $PM_{2.5}$ concentrations measured in lower SE areas were considerably higher than those in medium and high areas regardless of smoking area compliance. These results echo those of the pilot study which concluded that vapour phase nicotine was highest in smoking areas located in low SE areas. All of the smoking areas in venues located in low SE areas were in the suburbs, which is theorised as a truer representation of customer SES. Venues within high SE areas were more evenly distributed across the city centre and suburbs. Dublin is the capitol of the Republic of Ireland, which means the customers visiting its hospitality venues may be from all parts of Dublin, Ireland and the rest of the world, making it difficult to define their socioeconomic backgrounds. Smoking areas within venues located in high SE areas had 63.4% non-compliance while those within venues in medium SE areas had a more even split, 51.8% compliant and 48.2% non-compliant.

Regardless of venue socioeconomic status, non-compliant smoking areas had higher mean $PM_{2.5}$ concentrations. The non-compliant smoking areas were found in venues across the county irrespective of SES, an indication of the industries disregard for the legislation and the lack of enforcement.

An important result to note from the study was that the presence of boundary structures, whether that be a permanent wall or other structure, where more than 50% of the area was surrounded, $PM_{2.5}$ concentrations were higher ($p < .001$). This was also the case where roofs were present, irrespective of the type of roof and how much of the area it covered. The presence of a roof, which was the case for 77% of the smoking areas, resulted in higher $PM_{2.5}$ concentrations compared to areas with no roof ($p < .001$). Smoking areas with a roof had higher mean $PM_{2.5}$ concentrations irrespective of how much of that area was surrounded by a perimeter structure. However, the combination of both a roof and more than 50% of the perimeter of that area surrounded by one or more walls or similar structures had the highest $PM_{2.5}$ concentrations.

The results of this study demonstrate that the industry has strayed from the original idea of the designated smoking shelter and has now become a desirable space for customers to visit. 97% of the smoking areas visited had ample comfortable seating, 64% had comfortable seating as well as a television and/or music playing and/or games for customers to play. 61% of smoking areas had gas heaters. All of these amenities contributed to the creation of comfortable environments for smoking and non-smoking customers. This raises the question directed at hospitality venue owners and managers, why are they catering to their smoking customers?

As expected, $PM_{2.5}$ concentrations were significantly lower indoors, where smoking is banned. While some venues had higher mean values, this may have been due to drift from the smoking area, open kitchen areas or poor ventilation for example. Regardless, even the highest recorded mean $PM_{2.5}$ indoors was significantly lower than the max level recorded within a smoking area.

When $PM_{2.5}$ measurements were taken before the Irish smoking ban and compared with those taken after the ban, average $PM_{2.5}$ dropped by 83.6% from 35.5 to 5.8 $\mu g/m^3$ (Goodman *et al.*, 2007). The average $PM_{2.5}$ found for designated smoking areas in this study was 31.5 $\mu g/m^3$, close to those levels recorded within hospitality venues before the smoking ban. If we compare the average indoor $PM_{2.5}$ measurements from this study to that of Goodman *et al.* 2007 study, indoor $PM_{2.5}$ has increased from 5.8 to 11 $\mu g/m^3$. Further study in this area along with tobacco specific measurements would provide a better insight as to why indoor air quality has decreased since the postban studies. It could allow employers to introduce ventilation methods and improve smoke drift at access and egress points to a designated smoking area.

The sampling results were categorised using the Environmental Protection Agencies Air Quality Index for Health. This gave a useful insight into how these concentrations would be dealt with if they were recorded at ambient levels. 69% of smoking areas were graded 1-3 on the Index, classified as Good air quality. 17% were graded 4-6 and classified as Fair air quality. At this point, at-risk individuals would be advised to reduce strenuous physical activity, particularly outdoors. 3% of smoking areas were graded 7-8 which classified them as Poor air quality. In these cases, the general population would be advised to reduce activity, particularly outdoors, while at-risk individuals would be advised to reduce strenuous physical activity, particularly outdoors if experiencing symptoms, those with asthma may need to use their inhalers. Finally, 11% of the smoking areas visited would be categorised as having Very Poor air quality which would see all individuals advised to reduce outdoor activity (see appendix 7.3 for full chart).

5.2 Employee exposure to ETS

The results of this investigation have proved that exposure is still occurring in the hospitality industry, particularly in smoking areas with auxiliary bars. Employees were noted within 88% of the smoking areas surveyed with the majority spending less than 5 minutes at a time within the area. Employees were noted spending more than 15 minutes in 16% of the smoking areas, increasing their risk of adverse health effects due to ETS exposure. Worryingly, employees were noted working within 23% of the smoking areas in the upper quartile, with $PM_{2.5}$ concentrations ranging from 41 – 189 $\mu g/m^3$.

As shown in the results, peak exposure was often very high within the smoking areas. Short peak exposures are associated with the exacerbation of respiratory symptoms, asthma and single exposure events can damage blood vessels and increase the risk for platelet aggregation (Zhang *et al.*, 2020) (CDC, 2020b).

In terms of ambient air quality, the majority of employees were working in environments classified as having Good ambient air quality, however, 30% of employees were working in environments with fair, poor and very poor ambient air quality classifications. Irrespective of these recordings, exposure to ETS within the workplace should not be occurring, and the results of this study have shown that employees are spending time in smoking areas.

In the pilot study of 20 smoking areas, 15% of the smoking areas contained an auxiliary bar. In this study of 75 smoking areas, 21.3% contained an auxiliary bar. This raised the question as to whether these were no longer designated smoking areas, but rather an extension of the licenced premises. These bars contravene the main aim of the Public Health (Tobacco) (Amendment) Act 2004, having regard to Article 8 of the WHO Framework Convention of Tobacco Control. As a possible contributing factor to the asthma phenotype, increasing the risk of respiratory infections (CDC, 2006) (Geng *et al.*, 1995), along with lung cancer and coronary heart disease in non-smoking adults, the health of the employees was compromised wrongfully through occupational exposure.

Eighty-seven per cent of the auxiliary bars were located in non-compliant smoking areas, further reducing the ability of fresh air to circulate. These auxiliary bars should not be present and employees should not be expected to work there. Sixty-nine per cent of these auxiliary bars had one or more employees working full time during the sampling period of 45 minutes – 1 hour, within this time 54% were working in environments with fair, poor or very poor AQIH categorisations. Seven employees were noted spending the entire sampling period at an auxiliary bar within a smoking area with $PM_{2.5}$ concentrations in the upper quartile. While customers and smoking customers choose to be exposed to ETS, employees do not and should not be expected to work in these environments, irrespective of how low or high the $PM_{2.5}$ concentrations are.

The operation of food service within the smoking areas was another important observation for employee exposure assessments. In 54.7% of venues, food was served to customers seated within the designated smoking area. Where food service occurred, the instance of employees was higher. The time employees spent within the smoking areas was also higher across all times recorded.

When the sampling time was observed, $PM_{2.5}$ concentrations were higher at night time, an expected result based on the pilot study. An unexpected outcome, but understandable now given the circumstances, was that the annual $PM_{2.5}$ concentrations were lower in 2020 than in 2019. While the hospitality sector did close due to public health restrictions, a similar number of venues were sampled across both years (38 and 37 consecutively). In 2020, 25 smoking areas were visited after the first major public health restrictions were lifted in July. It could be assumed that the lower annual measurements resulted from various contributing factors, for example, a general drop in social gatherings, public avoidance of crowded indoor environments, social distancing measures reducing capacity and public health warnings to smokers. It is already understood that tobacco use is a risk factor for severe disease and death from multiple respiratory infections, and when the new virus was studied, it was concluded that smokers are associated with increased severity of disease than non-smokers (WHO, 2020b) (HSE, 2020). Additionally, in hospitalised patients, smokers are at an increased risk of severity of illness and death (WHO, 2020b) (Reddy *et al.*, 2020), as well as negative progression and adverse outcomes more so than never-smokers (Vardavas and Nikitara, 2020) (Vardavas and Nikitara, 2020).

5.3 The effect of COVID-19

In March 2020, the government of Ireland announced that all pubs, bars and clubs were required to close in the interest of public health. When the phased reopening of the country was announced, the hospitality industry was given dates and specific guidelines to adhere to in order to protect their customers. These living with COVID-19 guidelines resulted in a significant difference in the way in which the sampling could be carried out. The 3-month closure also affected the number of businesses that survived, resulting in 13 venues having to be removed from the finalised sampling list and a further 12 were incomplete due to public health restrictions which were tightened again in October.

From June 29th, only venues serving food could open. The final phase, which was scheduled for July 20th was postponed due to the rise in COVID-19 cases. Venues that couldn't supply food had to be scheduled for sampling later in the phased reopening which was delayed and ultimately "wet pubs" remained closed. Many venues that had outdoor spaces previously used as the smoking area were utilised as extra seating areas to accommodate social distancing. Outdoor dining of maximum 15 customers was in place during a portion of the phased reopening, and so in these establishments, employees were guaranteed to be spending time within the outdoor spaces, where smoking was observed except in one venue (SA81) which utilised its enclosed designated smoking area as a non-smoking "outdoor" dining area.

In regard to the research, no changes were made to the observational forms in order to keep the records consistent. The method in which sampling was approached did change with the requirement of booking ahead and requesting seating within the venues smoking area. The reduction in capacity due to social distancing made acquiring a table booking difficult. Some venues were prioritising food service over smoking customers meaning reservations were required to sit in the outdoor areas. Many venues doing this also banned smoking as the area was now a food service area.

Some observations which may be due to COVID-19 include the lower annual mean $PM_{2.5}$ concentrations. In 2019 the mean $PM_{2.5}$ was 37.3 µg/m³ while in 2020 it dropped to 25.6 µg/m³. As mentioned in the previous section, factors such as the general drop in social gatherings in hospitality venues, public health warnings to still avoid crowded environments, and capacity reductions due to social and public health warnings to smokers could have all contributed. In addition to these factors, pandemic unemployment is thought to have reduced disposable income used for eating and drinking in restaurants.

When measurements for the year 2020 were divided by pre COVID restrictions and after when these restrictions gradually lifted, $PM_{2.5}$ concentrations were not significantly different (24.5 $\mu g/m^3$ and 26.1 $\mu g/m^3$ respectfully). Food was served in 75% of smoking areas visited between January and March. This rose to 88% of smoking areas visited between July and October 2020, while public health guidelines placed restrictions on the hospitality industry, allowing only restaurants and pubs serving food to reopen. However, an increase of only 13%, some establishments opened without food service, a reflection of some hospitality non-compliance with the terms of opening set out by the National Public Health Emergency Team (NPHET).

5.4 Study limitations

Over the course of this study, a number of limitations were identified:

- The volunteers who partook in the health assessments were not representative of the employee population in the hospitality industry as they were all Caucasian. Future work should endeavour to recruit volunteers to represent the employee population of Ireland.
- The sample size of the health assessments meant that no statistically significant results were found. As this was a pilot study in the feasibility of assessments of this nature, acquiring healthy non-smokers willing to endure ETS exposure, sample numbers were limited and power calculations were not applicable. If expanded, a larger sample size should be acquired, along with a subset who will not be exposed to ETS as a control group.
- The smoking areas sampled were in venues located in Dublin only, no data was collected from smoking areas located in any other highly populated Irish cities or rural towns. The results are not a representation of the entire Republic of Ireland

and it must be noted that should this be expanded to a national scale, tobacco specific particles are necessary to differentiate from other sources of air pollution, for example smoky bituminous coal used outside of Dublin.

- There was only one smoking parameter measured. In future studies, $PM_{2.5}$ should be sampled alongside another marker for tobacco smoking e.g. vapour phase nicotine and benzene.

5.4.1 Limitations due to COVID-19:

Due to COVID-19, the hospitality industry was severely affected by closures in order to protect public health. Because of this, the following study limitations occurred:

A noted limitation of the pilot study was that the sampling period was limited to April-June. One of the aims of this study was to expand the sampling period to include all four seasons across the 12 months. Due to COVID-19, March, April, May and June 2020 were lost and sampling had to resume in July 2020 before ending in October 2020. Therefore, the project's sample size was smaller than originally planned due to COVID-19 restrictions. However, the final sample was still substantial at 75.

After the initial COVID-19 restrictions and closures, contact with many venues was required to book a space in their smoking areas, where possible. In addition to this, a government requirement of €9 minimum spend on food was in place. Pre-COVID, the most central table was chosen where possible to ensure there was no smoke source within less than 1 metre of the sampling device. When hospitality reopened, this was not possible at all times due to social-distancing requirements and pre-booked tables. During level 3 restrictions in Dublin, only outdoor dining was allowed. Due to this some venues (n= 4) had no indoor $PM_{2.5}$ recorded due to restrictions on entry to the premises at the time of visit.

One of the noted limitations of the pilot study was that day time and night time measurements could not be directly compared as they did not take place within the same smoking area. An aim of this study was to address this limitation by revisiting a subset of smoking areas for a second visit at an alternate time of the day. Unfortunately, this was not completed as the addition of as many smoking areas to the data set as possible was prioritised before level 5 restrictions were enforced again.

Chapter six: Conclusions and recommendations

6. Introduction

Based on this study, a number of important conclusions were drawn from the results of the $PM_{2.5}$ sampling, smoking area observations and health assessments. Simultaneously, some recommendations for future study were compiled to further develop information available on this topic and to address the limitations mentioned section 7.4.

6.1 Key conclusions

The aim of this research project was to gather data on non-compliance with the Public Health (Tobacco) Acts within the hospitality industry in Dublin, in order to provide evidence based policy recommendations. The study also set out to investigate occupational exposure to environmental tobacco smoke within the industry to determine the current instance of workplace exposure to environmental tobacco smoke. The following conclusions were drawn from the research:

- 60% of smoking areas were deemed non-compliant with the Public Health (Tobacco) Acts.
- Non-compliant smoking areas had higher average $PM_{2.5}$ concentrations ($p < .001$).
- Average $PM_{2.5}$ concentrations were highest in smoking areas with a low socioeconomic status.
- Smoking areas located in medium and higher socioeconomic areas had similar concentrations.
- The majority of non-compliant smoking areas were located in Dublin's suburban areas. The overall distribution of venues demonstrated that non-compliance was evenly distributed across the county.

- Smoking areas that had a perimeter boundary of more than 50% of the area, had higher average $PM_{2.5}$ levels than in those areas with a perimeter of less than 50% ($p < .001$).
- Average $PM_{2.5}$ was significantly higher in smoking areas where a roof of any kind was present ($p < .001$).
- Employees were noted working within 88% of the smoking areas visited, with the majority spending less than 5 minutes there during the sampling period.
- A permanent auxiliary bar was present in 21.3% of smoking areas surveyed, a direct breach of the Public Health (Tobacco) Acts enacted for the protection of employees from ETS exposure.
- Mean $PM_{2.5}$ was significantly higher within the smoking areas than inside the non-smoking area of venue ($p < .001$).
- While immediate effects on health were not as was expected, this does not negate the possibility of a negative effect on health from long term exposure on the individual.
- When immediate effects of ETS exposure were assessed, peak flow results were suggestive of an effect between pre exposure and during exposure ($p = .051$), pre exposure and post exposure ($p = .057$). No significant health effects were noted.

6.2 Recommendations for replication or future study on this topic

If this study was to be revisited or recreated, a larger group of volunteers should be acquired of various age and race in order to determine the immediate effects of environmental tobacco smoke exposure. This study of 10 volunteers was inconclusive but did highlight challenges involved in recruitment of volunteers to knowingly increase their risks of adverse health effects, irrespective of their own voluntary exposure in the form of visits to smoking areas during socialising at pubs and clubs. If time and funding were available, more long term exposure assessments would also provide an interesting look into the current state of health among hospitality employees, specifically with the use of personal monitors. The addition of a simple questionnaire provided to employees could provide insight into their attitudes towards their perceived exposure, if any, along with their opinions on current regulations and if they feel protected or unprotected by the Public Health (Tobacco) Acts.

It is recommended that two or more markers of tobacco smoke be used in future studies. In doing so, other sources of air pollution may be noted and controlled for. For example, vapour phase nicotine is an indicator of tobacco smoke and e-cigarette vapour. In this study, while other sources of $PM_{2.5}$ were noted, it was ultimately beyond the abilities of the sampling equipment to differentiate between $PM_{2.5}$ from a cigarette and $PM_{2.5}$ from a gas heater or car exhaust pipe.

Finally, the sampling method of noting the number of smokers at 0, 15, 30, 45 and 60 minutes resulted in an inability to decipher a correlation between active smokers and $PM_{2.5}$ concentrations. Average smokers and average $PM_{2.5}$ also had no correlation. And so, a method to successfully quantify active smokers and $PM_{2.5}$ concentrations is recommended. The recording of smokers at shorter time intervals and the use of an additional sampling device are possibilities to achieve this.

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Chapter seven: Appendices

7.1 Smoking prevalence

The below figures are taken from the HSE tracker and feature the breakdown of smoking per socio-economic group

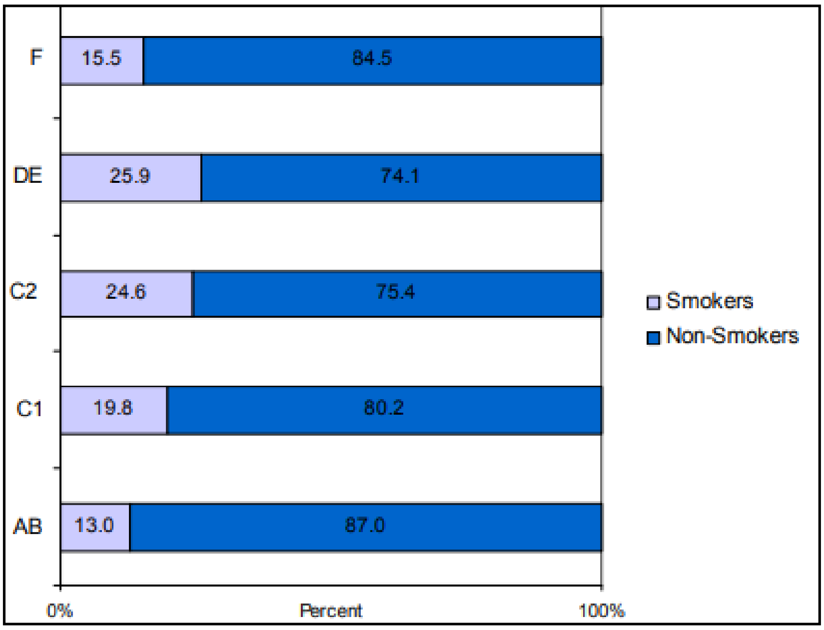

Figure 7.1: 2013 (Hickey and Evans, 2014)

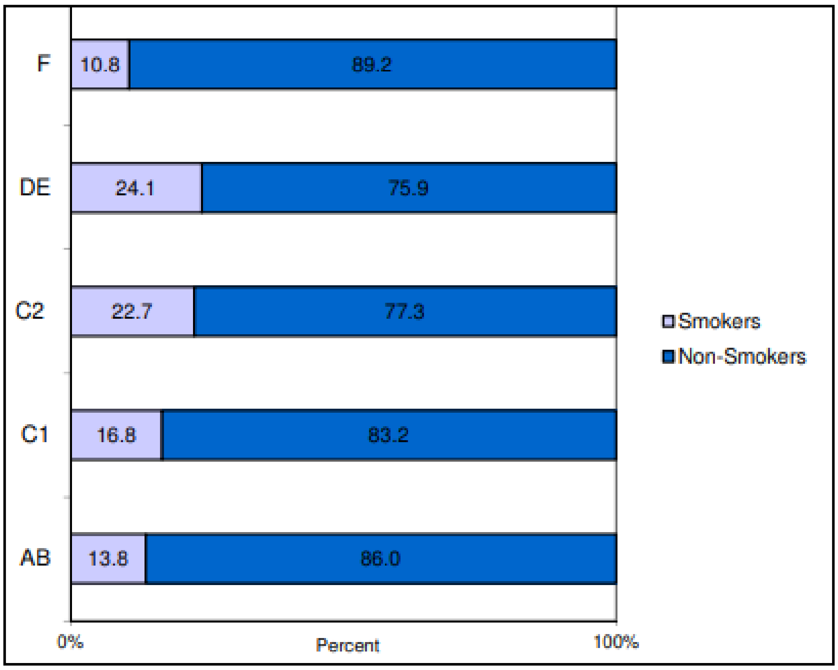

Figure 7.2 : 2014 (Hickey and Evans, 2015)

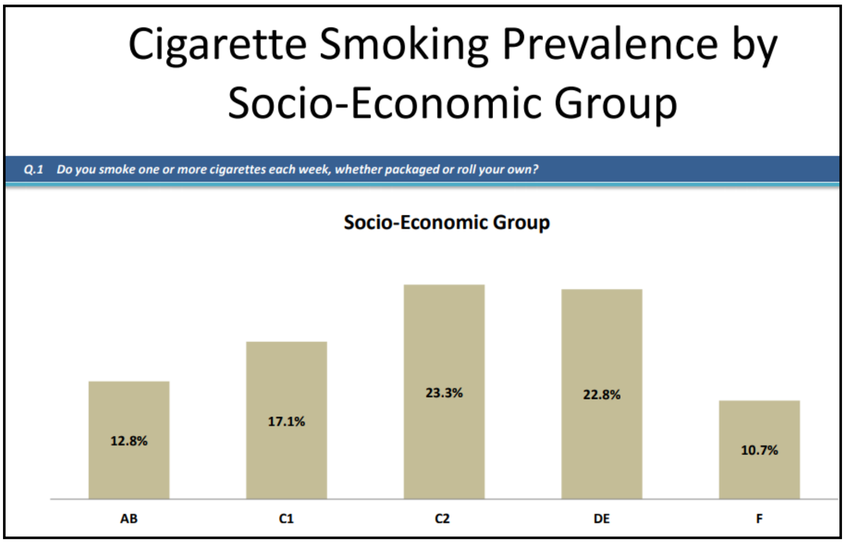

Figure 7.3: 2015 (HSE, 2015)

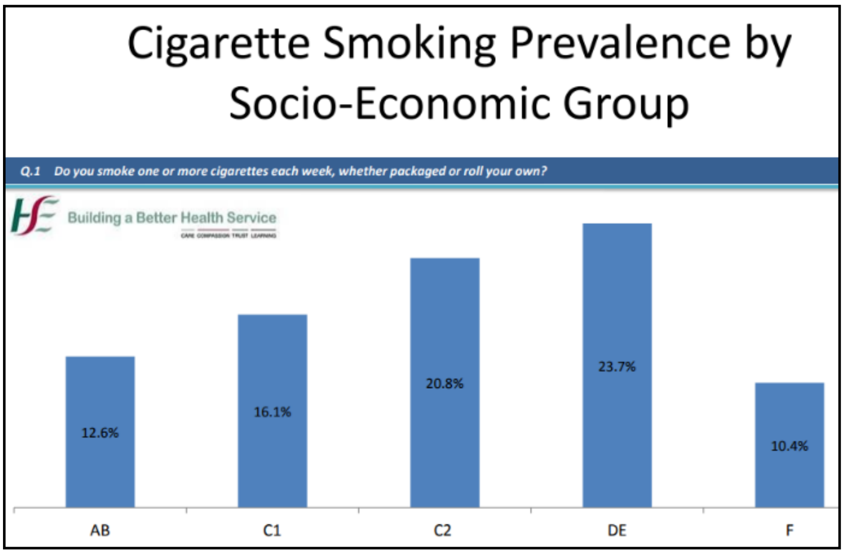

Figure 7.4: 2016 (HSE, 2016)

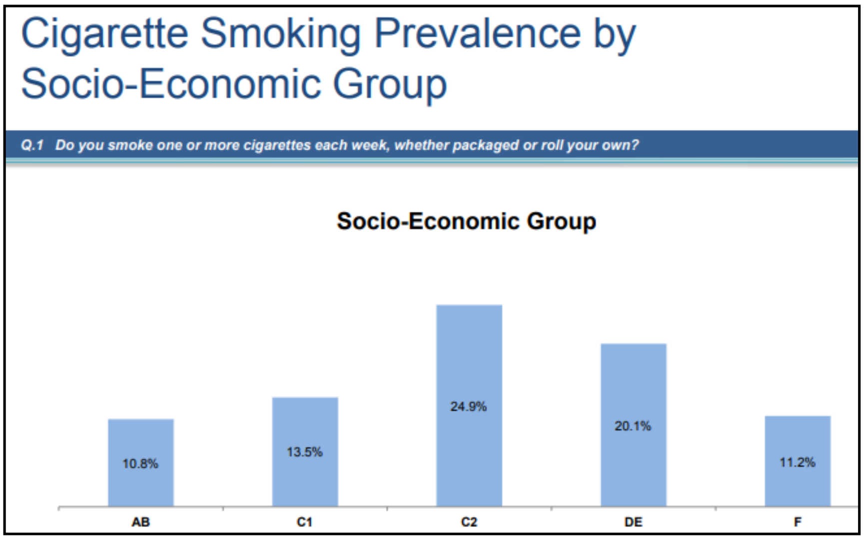

Figure 7.5: 2017 (HSE, 2017)

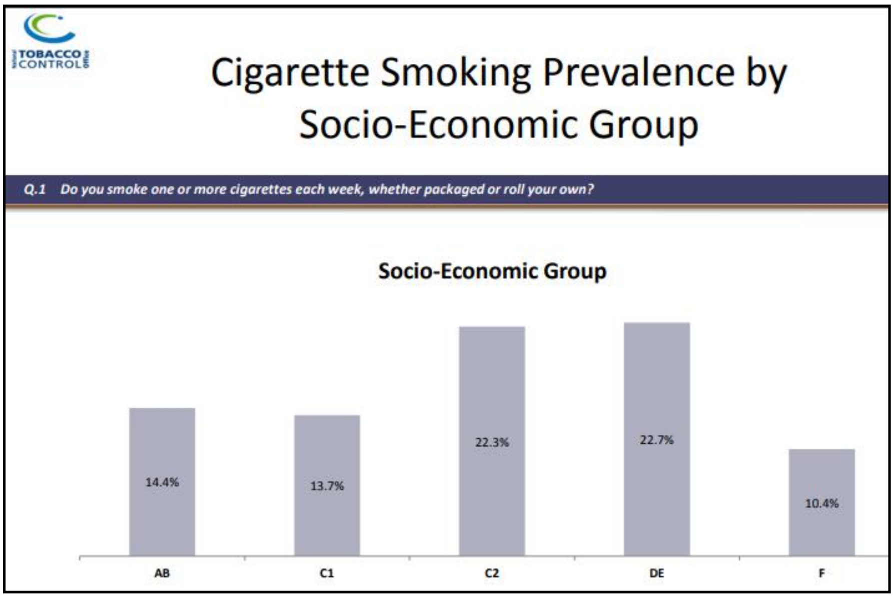

Figure 7.6: 2018 (HSE, 2018a)

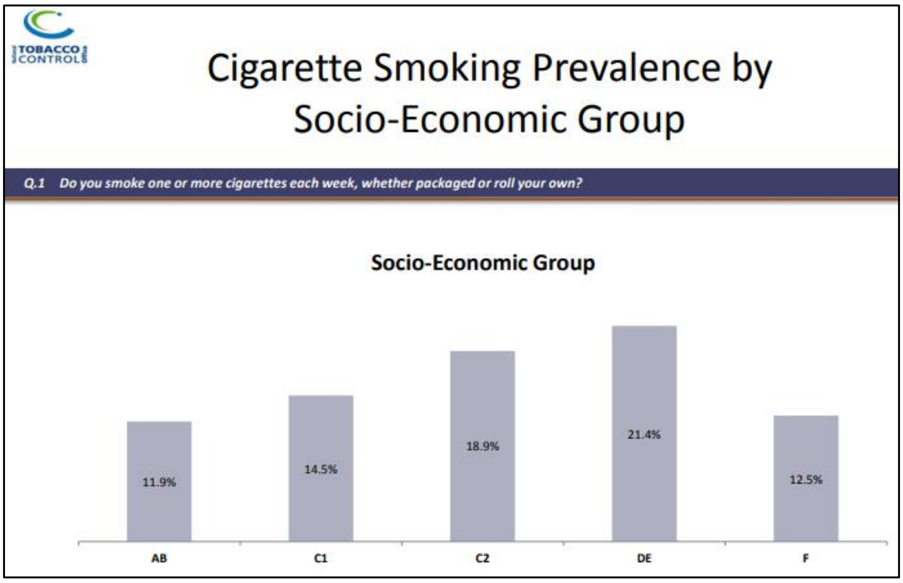

Figure 7.7: 2019 (HSE, 2019)

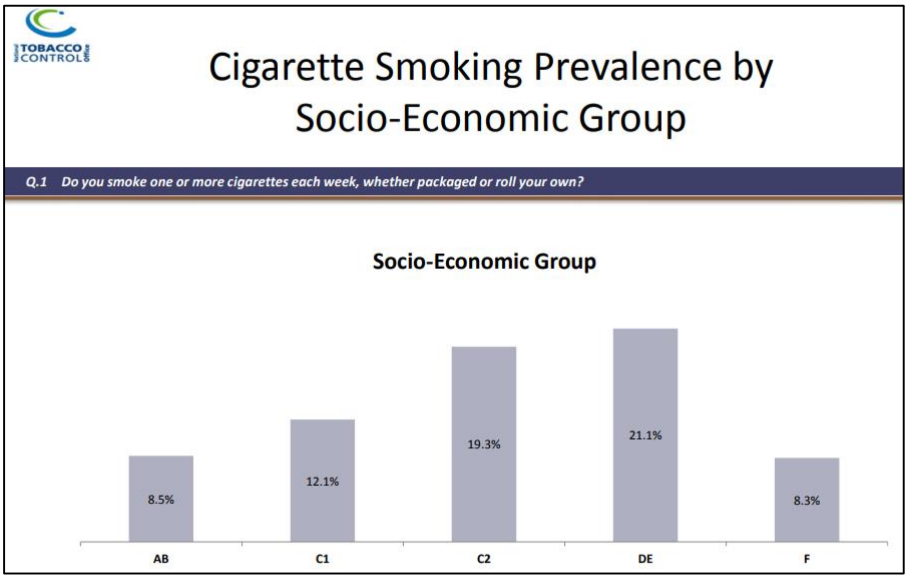

Figure 7.8: 2020 half year update (HSE, 2020b)

7.2 Background ambient air quality

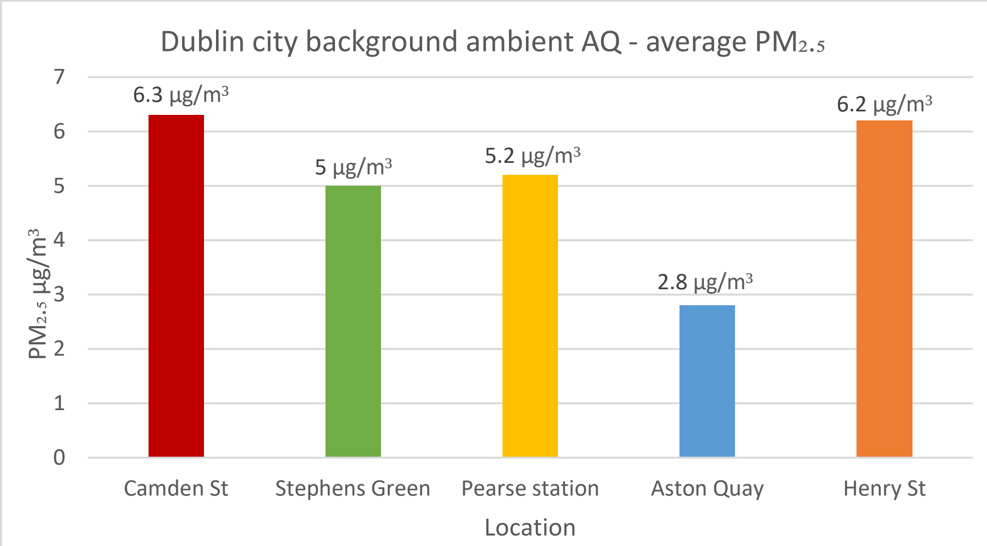

Figure 7.9: The above graph shows the results of background ambient air quality measured in various locations around Dublin in 2019. Each location was sampled for a 20-minute period using the SidePak AM510. No legislative exceedances were found. This was as expected as the EPA Air Quality Index consistently shows air quality in Dublin as good with annual mean $PM_{2.5}$ concentrations ranging from 8- 11µg/m^3 for 2019.

7.3 Environmental Protection Agency Air Quality Index for Health

Four bands of air quality:	Index (1-10):	Ozone Running 8-hour mean (µg/m³)	Nitrogen dioxide 1-hour mean (µg/m³)	Sulphur dioxide 1-hour mean (µg/m³)	$PM_{2.5}$ particles Running 24-hour mean (µg/m³)	PM_{10} particles Running 24-hour mean (µg/m³)
		Five air pollutants which can harm your health:				
Good air quality	1	0-33	0-67	0-29	0-11	0-16
	2	34-65	68-134	30-59	12-23	17-33
	3	67-100	135-200	60-89	24-35	34-50
Fair air quality	4	101-120	201-267	90-119	36-41	51-58
	5	121-140	268-334	120-149	42-47	59-66
	6	141-160	335-400	150-179	48-53	67-75
Poor air quality	7	161-187	401-467	180-236	54-58	76-83
	8	188-213	468-534	237-295	59-64	84-91
	9	214-240	535-600	296-354	65-70	92-100
Very Poor air quality	10	241 or more	601 or more	355 or more	71 or more	101 or more

Figure 7.10 The four bands of air quality as defined by the AQIH

Band	Index	Accompanying health messages for at-risk groups and the general population	
		At-risk individuals *	General population
Good	1	Enjoy your usual outdoor activities.	Enjoy your usual outdoor activities.
	2		
	3		
Fair	4	Adults and children with lung problems, and adults with heart problems, who experience symptoms, should consider reducing strenuous physical activity, particularly outdoors.	Enjoy your usual outdoor activities.
	5		
	6		
Poor	7	Adults and children with lung problems, and adults with heart problems, should reduce strenuous physical activity, particularly outdoors, and particularly if they experience symptoms. People with asthma may find they need to use their reliever inhaler more often. Older people should also reduce physical exertion.	Anyone experiencing discomfort such as sore eyes, cough or sore throat should consider reducing activity, particularly outdoors.
	8		
	9		
Very Poor	10	Adults and children with lung problems, adults with heart problems, and older people, should avoid strenuous physical activity. People with asthma may find they need to use their reliever inhaler more often.	Reduce physical exertion, particularly outdoors, especially if you experience symptoms such as cough or sore throat.

Figure 7.11: Accompanying health messages to the AQI bands of air quality.

7.4 Health assessment methods and equipment set up.

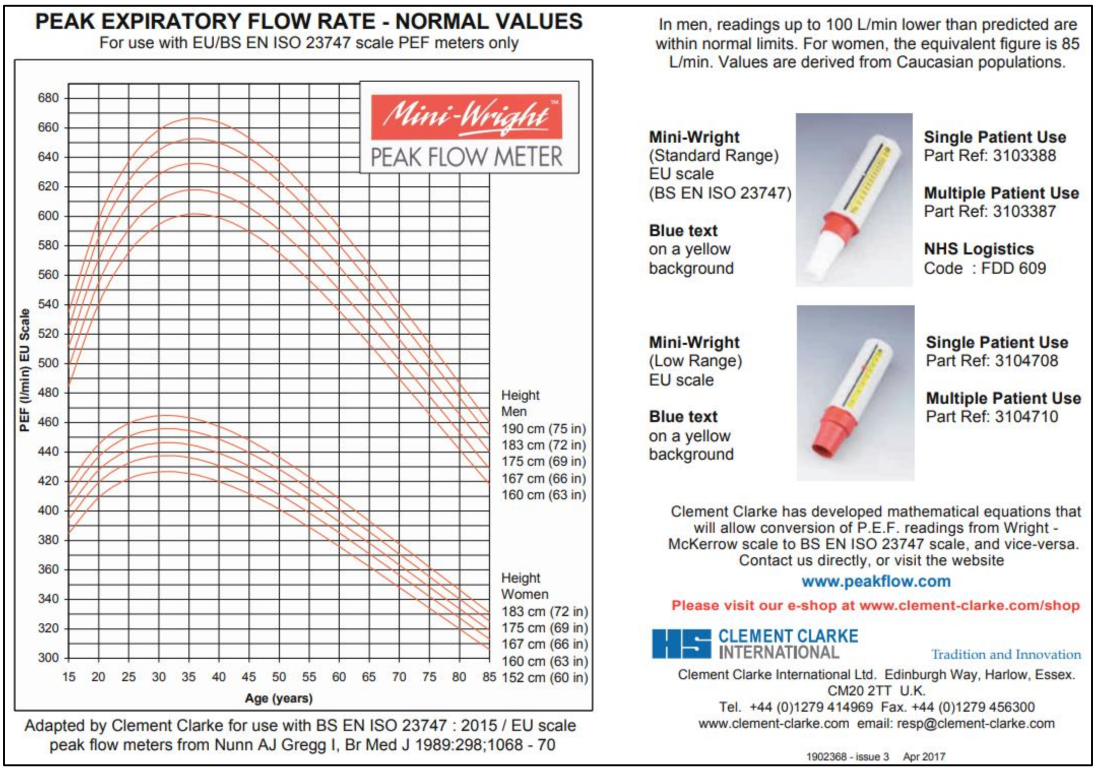

Figure 7.12: Normal values for peak expiratory flow rate.

1. Order of tests:

    a. Begin air sampling

    b. Spirometry pre exposure

    c. Carbon monoxide pre exposure

    d. Peak flow pre exposure

    e. Exposure to ETS for 45 mins – 1 hour & peak flow during exposure

    f. Spirometry post exposure

    g. Peak flow post exposure

    h. Carbon monoxide post exposure

2. Spirometry, CO and peak flow rate pre exposure was recorded no more than 2 hours prior. Followed by 45 minutes - 1-hour exposure to second-hand smoke, during which

peak flow was tested. Spirometry was then recorded as close to the end of exposure after repeating peak flow and CO.

3. Consent forms were obtained from each volunteer for CO monitor, peak flow and spirometer prior to the sample period.

4. A short questionnaire on smoke exposure was completed by each volunteer.

7.4.1 Spirometer protocol:

1. Record volunteer ID and time. This must be no more than 1-2 hours pre and post attendance at a smoking shelter.
2. The mouthpiece was plugged into the holder and a new cardboard mouthpiece was placed in as shown below.

3. Spirometer was turned on and using the stylus, selected “forced spirometry”.
4. Data was filled in for the volunteer e.g. sex, age, height, weight (a converter app was used to input weight in kg and height in centimetres).
5. The volunteer was briefed that they would be required to take a deep breath, filling their lungs, and blow out as hard and fast as they could, ensuring the lips were sealed around the mouthpiece.
6. This was repeated three times, noting the results which would generally be seen within the grey zone on the screen.
7. Selected “finish” and the results screen loaded.

8. Recorded FEV1 Value and % Predicted, FVC Value and % Predicted and PEF Value and % Predicted.
9. Selected “done”, then “save” and input patient ID number, date of birth and whether they were a smoker or non-smoker.
10. This was repeated as soon as possible after leaving the smoking area.
11. The cardboard mouthpiece was disposed of.
12. To upload data to computer, software was installed. The machine was placed in the dock and connected to the computer. On screen instructions were followed.

7.4.2 Exhaled carbon monoxide

1. The volunteer ID, venue code and time was recorded.
2. A new cardboard mouthpiece was inserted into the plastic holder and breathalyser as shown in picture below.

3. The volunteer was briefed that they would need to take a deep breath in, hold for 20 seconds and slow exhale once instructed, ensuring the lips were sealed around the mouthpiece.
4. The machine was turned from OFF to CO-PPM.
5. Once the screen showed “20”, a deep inhale was taken and held as it counted down to “0”.
6. Exhaled strong and steadily for approximately 10 seconds.
7. The value in PPM shown on screen was recorded.

8. This was repeated as soon as possible after leaving the smoking area, and again within 2 hours of exposure.
9. The cardboard mouthpiece was disposed of.

Note: normal reading 0 – 6 range.

7.4.3 Peak flow

1. Checked volunteer ID, venue code and time was recorded.
2. A new cardboard mouthpiece was inserted.
3. Volunteer was instructed to take a deep breath and hold before short, sharp exhale.
4. This was repeated three times and the highest result was recorded.
5. After arrival at the venue, the sampler was turned on and a 2-5 minute sample was recorded inside the smoke free area.
6. Once situated in the designated smoking area, the SidePak was switched on for data logging to commence. The start time was noted and the SidePak was placed at table height.
7. Whilst data logging, the observational data was recorded.
8. Once the sampling period concluded, the SidePak was turned off.
9. Using the TSI TrakPro software, test results were downloaded from the SidePak and recorded within the venues coded file.

7.5 Observational data form for ETS exposure in hospitality venues

<table>
<tr><td colspan="6">Venue code: ______________ Date of sampling: _______________
HE volunteer: Y / N ____________ Ambient background AQ: ___:___-___:___</td></tr>
<tr><td>Time* of day:</td><td>Daytime**</td><td colspan="2">Night time***</td><td>1st visit</td><td>2nd visit</td></tr>
<tr><td>Room size est.</td><td colspan="3">______ m by</td><td colspan="2">_______ m</td></tr>
<tr><td colspan="3">Sample time period: ___:___ - ___:___</td><td colspan="3">+Humidity (%): _____ Temp (ºC): ______</td></tr>
<tr><td>Perceived wind level:</td><td colspan="2">Calm</td><td colspan="2">Light to Moderate</td><td>Very windy</td></tr>
<tr><td colspan="6">Rough location/venue location type: Local / suburban City centre</td></tr>
<tr><td colspan="2">Venue socio economic status++:</td><td colspan="4">High Intermediate/Medium Low</td></tr>
<tr><td colspan="2">Size of venue:</td><td colspan="4">Small (<50 patrons) Medium (50-100 patrons) Large (>100 patrons)</td></tr>
<tr><td>Smoking area+++:</td><td colspan="5">Compliant Non-compliant</td></tr>
</table>

Roof: Yes / No

Fixed – Full / Half **Movable** – Open fully / half open / closed

No. of perimeter boundaries: more than 50%? Yes / No

- Permanent walls: __
- Half permanent walls: __
- Hedges/ shrubbery: __
- Glass perimeters: __

Is there food served in the area? Yes / No

Presence of permanent outdoor bar: Yes / No

If **yes,** how many staff present there: _____

Leisure amenities: (tick all that apply)

☐ Games e.g. pool tables, darts
☐ Comfortable seating e.g. couches, blankets, cushions
☐ TV screens playing sport, music channels, news
☐ Music playing through speakers/ DJ/ Band situated in smoking area

Presence of other potential sources of PM: (tick all that apply)

- ☐ Fireplace/ fire pit/ candles
- ☐ BBQ
- ☐ Cooking vents
- ☐ Close proximity to heavy traffic
- ☐ Gas heaters

Staff present in smoking area during sampling period: Yes / No

- ☐ 1-3 staff members spending 0-5 minutes in area each time entered
- ☐ 3-5 staff members spending 0-5 minutes in area each time entered
- ☐ >5 staff members spending 0-5 minutes in area each time entered
- ☐ 1-3 staff members spending 5-15 minutes in area each time entered
- ☐ 3-5 staff members spending 5-15 minutes in area each time entered
- ☐ >5 staff members spending 5-15 minutes in area each time entered
- ☐ 1-3 staff members spending >15 minutes in area each time entered
- ☐ 3-5 staff members spending >15 minutes in area each time entered
- ☐ >5 staff members spending >15 minutes in area each time entered
- ☐ ___ staff members present for ___mins

Number of customers present in the smoking area during the sampling period:

0mins: 15mins: 30mins: 45mins: 60mins:

Number of customers smoking in the smoking area during the sample period:

0mins: 15mins: 30mins: 45mins: 60mins:

Number of e-cigarette users in the smoking area during the sample period:

0mins: 15mins: 30mins: 45mins: 60mins:

Presence of children under 12 at any point? Yes / No

Presence of ashtrays: Yes / No

Presence of cigarette butts in ashtrays: Yes No

If **yes,** approximately how many: _____

Presence of designated smoking area signage: Yes / No

Comments:

**each form is based on a 45-60 minute sampling period*

***Daytime = noon – 6pm*

****Night time= 6pm – late*

[+]Humidity and temperature as recorded on The Weather Channel Application

[++]Based on Pobal 2016 deprivation indices where:

- *“High” = extremely affluent/ very affluent/ affluent*
- *“Intermediate/ Medium” = marginally above average/ marginally below average*
- *“Low” = disadvantaged/ very disadvantaged/ extremely disadvantaged*

[+++]Compliant smoking shelter As defined by the Public Health (Tobacco) (Amendment) Act 2004 section 47: “A place or premises, or a part of a place or premises, that is wholly uncovered by any roof”, “an outdoor part of a place or premises covered by a fixed or movable roof, provided that not more than 50 per cent of the perimeter of that part is surrounded by one or more walls or similar structures (inclusive of windows, doors, gates or other means of access to or egress from that part)” (Public Health (Tobacco) (Amendment) Act, 2004).

7.6 Health assessment forms

7.6.1 Ethical approval

Institiúid Teicneolaíochta Átha Cliath, Sráid Caoimhín, Baile Átha Cliath 8, Éire
Dublin Institute of Technology, Kevin Street, Dublin 8, Ireland
www.dit.ie/graduateresearchschool

SCOIL TAIGHDE IARCHÉIME / GRADUATE RESEARCH SCHOOL
Professor Mary McNamara

6th November 2014

Prof. Luke Clancy
Tobacco Free Research Institute Ireland
Dublin Institute of Technology
Kevin St
Dublin 8

Re: Ethical Clearance Ref 14-72

Dear Luke

I am pleased to inform you that the following project:

'New approaches to monitoring exposure to air pollution and health effects'

which you submitted to the Research Ethical Committee has been approved. The committee would like to wish you very best of luck with the rest of research project. If you have any further queries, please do not hesitate to contact Conor McCague on (01) 402 7920 or at conor.mccague@dit.ie.

Yours sincerely

Dublin Institute of Technology
Research Ethics Committee

Coláistí: Ealaíon & Turasóireacht | Gnó | Innealtóireachta & Timpeallacht Tógtha | Eolaíochtaí & Sláinte |
Colleges: Arts & Tourism | Business | Engineering & Built Environment | Sciences & Health |

7.6.2 Information and consent form

New approaches to monitoring exposure to air pollution and health effects

Information and consent form – health effects of smoke exposure

What is this study about?

This study aims to assess smoking areas in Dublin, with the objective to investigate hospitality employees' exposure to second-hand smoke whilst in the workplace. Smokefree legislation has been successful in its primary aim of eliminating smoking in public indoor places. However, the exemptions allowed for within the law (i.e. smoking areas in pubs, smoking in prisons and nursing homes, and smoking within the home) raise further challenges. Along with adults, children are often exposed to second-hand smoke in homes, cars, and sporting venues. Our previous research has also shown that children are also exposed to Second-hand Smoke in cars in sporting venues and at home. As partners in the EU funded IMPASHS project we are aware of the undesired complications of the exemptions to the legislation.
To date, it has been very difficult to gather accurate, objective data on second-hand smoke exposure among adults in Ireland. One of the main aims of this study is to measure Second-hand smoke exposure during everyday activities and monitor the associated health effects.

How do you measure air pollution?

Air pollution will be measured through the use of a small portable instrument that can continuously and rapidly record changes in the air through the measurement of suspended particles. Breathing will be measured by Spirometry and exhaled breath gases (e.g. Carbon Monoxide). These tests will not cause any undue discomfort or inconvenience to participants.

What does participation involve?

Step One: A researcher will contact you by phone to discuss participation in further detail and answer any questions you may have.
Step Two: If you agree to take part: A researcher will arrange an appointment for you, where

- Any queries you may have will be addressed.
- You will be given an information sheet and a consent form, which you will be asked to read and sign.
- You will have Spirometry (Breathing test) recorded, a maximum of three manoeuvres will be performed and recorded pre and post visit to agreed smoking area.
- CO Readings which is a breath test will be carried out pre and post visit to agreed smoking area.
- Your peak flow breathing rate will be recorded pre, during and post visit.
- A short de-identified questionnaire which will ensure that your information is private will be carried out.

Do I have to participate?
Absolutely not. Participation is 100% voluntary. No one will be included in any stage of the research unless they have given consent. Participants can revoke consent at any stage of the process.

Will this be confidential?
All information that is gathered in this study remains 100% confidential. Your information will be stored in a de-identified form on a secure computer that is only used by members of the research team. No one will have access to the information gathered in this study aside from the researchers and it will only be used for research purposes. There will be no identifiable information stored in the computer at any stage during this research.

Who is running this study?

The Royal City of Dublin Hospital Trust (RCDHT) is funding this study with The TobaccoFree Research Institute (TRI) who is carrying out this research in exempted SmokeFree areas in Dublin. The TRI was formed on the basis of a partnership between the Office of Tobacco Control and ASH Ireland. The Institute supports the development of a tobacco free society by engaging in research in all aspects of tobacco from a public health perspective to provide the evidence base for action.

The researcher, Hannah Byrne, is pursuing her MPhil, fully funded by the Irish Research Council Employment Based Postgraduate Scholarship Programme in which the TobaccoFree Research Institute is the employer. Data gathered will be used in both the TRI project and her own thesis.

It is only by conducting studies such as these that we are able to understand the impact of Second-hand Smoke on our airways. Through studies like this, we are able to work towards promoting the health of people in Ireland and abroad.

We hope that you can support us in our work and we would thank you, in anticipation, for your help.

Patient Consent

I have read the information sheet pertaining to the '***New approaches to monitoring exposure to air pollution and health effects'*** project,

I understand that research is being conducted by Hannah Byrne on behalf of The TobaccoFree Research Institute Ireland and that my participation is completely voluntary.

I understand that by agreeing to take part in the study that it will involve me attending the research centre. Your **visit** will involve: written consent and explanation and conducting breathing tests followed by an agreed visit to a smoking area.

Signed:

Participant Name (Print): ____

Participant Signature: _______________________________________,

Date: ____________________________,

Investigator Name: (Print) ____,

Investigator Signature: ____,

Date: _____________________________,

7.6.3 Smoke exposure questionnaire

Smoke exposure short questionnaire

Researcher: Hannah Byrne

A short questionnaire to ascertain personal smoking status, other sources of exposure, average weekly exposure in hospitality premises, and experience of respiratory symptoms. Circle correct response where appropriate

Unique Identifier code: __________

Venue ID code: ______________

Please circle your answer and/ or fill in blanks where appropriate

1. Sex: Male Female
2. Age: ____
3. Do you ever smoke cigarettes/tobacco? Yes / No

   If yes

   - For how many years? ____
   - At what age did you start to smoke? ____
   - Do you smoke every day? ____
   - How many do you smoke on an average day? ____

4. Do you currently live with any smokers? Yes / No

   If yes

   - How many? ____
   - Do they smoke in the home? ____

5. Are you exposed to smoking in cars? Yes / No

   If yes

   - How many trips per week? ____
   - What is the average duration of these trips? ____

6. Do you visit smoking areas in the hospitality sector such as Pubs or Restaurants? Yes / No

   If yes:

   - How often per month? ____

Please continue ►

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7. Have you been diagnosed by a doctor with? Asthma COPD Neither

If yes how long is it since your diagnosis? ____

8. Do you suffer from any of the following?

Wheeze	Never	Sometimes	Often
Cough	Never	Sometimes	Often
Shortness of breath	Never	Sometimes	Often
Stinging or irritation of the eyes	Never	Sometimes	Often

7.6.4 Health data collection form

Researcher Data collection form – health effects

Individual ID: ___________ Venue code: ___________ Date: __ __ / __ __ / __ __	Collector Name: ____________________ Country : ____________________ City: ____________________

Date: dd / mm / yy; [3] Time: hh:mm (24hr)

Please, write down the following information: In pre filled in cells please circle clearly the correct choice.

Smoking Status	Current	Ex-Smoker		Non Smoker
Do you live with a smoker?	Yes		No	
Sex	Male		Female	
Diagnosis	COPD	Asthma		None
Age:				
Height:				
Weight				
	Baseline CO, PF & Spirometry Time: __hr __min		Post Exposure Co, PF & Spirometry Time: __hr __min	
Co Reading				
Peak Flow reading				
FEV1	Actual	% Pred	Actual	% Pred
FVC	Actual	% Pred	Actual	% Pred
PEFR	Actual	% Pred	Actual	% Pred

Please, write down the following information:

Start of Exposure time[3]	__ __ / __ __ / __ __					
End of Exposure time[3]	__ __ / __ __ / __ __					
Duration time of exposure (Hour/min):	__ __ / __ __					
Number of walls in premises	1	2	3	4		
Number of smokers present	0	1-5	6-10	11-15	16-20	>20
Number of E cig users present	0	1-5	6-10	11-15	16 -20	>20

Any unusual events during monitoring, (please list)	Time of event

Comments / Notes

7.7 Statistical data appendix:

7.7.1 Data for Figure 4.1: Do non-compliant smoking areas effect average $PM_{2.5}$.

venue	compliant	avg$PM_{2.5}$	venue	compliant	avg$PM_{2.5}$
84	compliant	13.2	4	non-compliant	83.3
6	compliant	7.3	83	non-compliant	15.2
82	compliant	34.9	58	non-compliant	55
33	compliant	12	34	non-compliant	15.5
45	compliant	4.5	94	non-compliant	20.8
25	compliant	16.1	96	non-compliant	49.5
76	compliant	30.5	97	non-compliant	9.3
29	compliant	16	26	non-compliant	21.9
28	compliant	28	61	non-compliant	46.1
49	compliant	34.8	5	non-compliant	24
14	compliant	5.8	54	non-compliant	71
79	compliant	5.1	62	non-compliant	101
91	compliant	40.8	31	non-compliant	20.9
92	compliant	16	50	non-compliant	93
93	compliant	9.7	11	non-compliant	101.4
43	compliant	18.3	19	non-compliant	6.6
35	compliant	8.1	20	non-compliant	8.2
98	compliant	27.1	55	non-compliant	9.7
2	compliant	9	21	non-compliant	24
42	compliant	2	36	non-compliant	40.2
3	compliant	28.3	59	non-compliant	32
23	compliant	1.4	67	non-compliant	189
8	compliant	16.9	39	non-compliant	31.9
52	compliant	17.9	27	non-compliant	26.7
16	compliant	33.3	18	non-compliant	2
7	compliant	29.6	30	non-compliant	1.8
1	compliant	17	60	non-compliant	24
15	compliant	4	70	non-compliant	39.4
57	compliant	14	41	non-compliant	40.2
9	compliant	15	13	non-compliant	48
			56	non-compliant	17
			17	non-compliant	12.5
			53	non-compliant	75.7
			37	non-compliant	47.8
			99	non-compliant	50.5
			10	non-compliant	18.5
			48	non-compliant	44
			77	non-compliant	42.6
			88	non-compliant	41
			89	non-compliant	59

			72	non-compliant	21.8
			44	non-compliant	2
			100	non-compliant	47
			81	non-compliant	2.2
			87	compliant	114.4

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	17.22	41.05777778
Variance	123.0568276	1325.253404
Observations	30	45
Hypothesized Mean Difference	0	
df	55	
t Stat	-4.115349795	
P(T<=t) one-tail	6.52735E-05	
t Critical one-tail	1.673033965	
P(T<=t) two-tail	0.000130547	
t Critical two-tail	2.004044783	

<u>t-Test excluding outlier 189 µg/m3:</u>

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	17.22	37.69545455
Variance	123.0568276	835.5074207
Observations	30	44
Hypothesized Mean Difference	0	
df	59	
t Stat	-4.261034094	
P(T<=t) one-tail	3.71325E-05	
t Critical one-tail	1.671093032	
P(T<=t) two-tail	7.4265E-05	
t Critical two-tail	2.000995378	

7.7.2 Data for figure 4.3: Did the socioeconomic status of the smoking areas location affect $PM_{2.5}$.

venue	SES	avg$PM_{2.5}$	venue	SES	avg$PM_{2.5}$
87	low	114.4	84	medium	13.2
28	low	28	4	medium	83.3
62	low	101	82	medium	34.9
30	low	1.8	29	medium	16
41	low	40.2	54	medium	71
10	low	18.5	31	medium	20.9
89	low	59	49	medium	34.8
			50	medium	93
			55	medium	9.7
			36	medium	40.2
			59	medium	32
			67	medium	189
			39	medium	31.9
			18	medium	2
			14	medium	5.8
			79	medium	5.1
			35	medium	8.1
			98	medium	27.1
			42	medium	2
			3	medium	28.3
			23	medium	1.4
			17	medium	12.5
			88	medium	41
			1	medium	17
			15	medium	4
			44	medium	2
			9	medium	15

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	51.84285714	31.15555556
Variance	1783.519524	1585.824872
Observations	7	27
Hypothesized Mean Difference	0	
df	9	
t Stat	1.168340174	
P(T<=t) one-tail	0.136342731	
t Critical one-tail	1.833112933	
P(T<=t) two-tail	0.272685463	
t Critical two-tail	2.262157163	

7.7.3 *Data for table 4.1: $PM_{2.5}$ measurements across all smoking areas by their socioeconomic status.*

venue	SES	avg$PM_{2.5}$	venue	SES	avg$PM_{2.5}$	venue	SES	avg$PM_{2.5}$
6	high	7.3	84	medium	13.2	28	low	28
33	high	12	82	medium	34.9	62	low	101
45	high	4.5	29	medium	16	30	low	1.8
25	high	16.1	49	medium	34.8	41	low	40.2
76	high	30.5	14	medium	5.8	10	low	18.5
91	high	40.8	79	medium	5.1	89	low	59
92	high	16	35	medium	8.1	87	low	114.4
93	high	9.7	98	medium	27.1			
43	high	18.3	42	medium	2			
2	high	9	3	medium	28.3			
8	high	16.9	23	medium	1.4			
52	high	17.9	1	medium	17			
16	high	33.3	15	medium	4			
7	high	29.6	9	medium	15			
57	high	14	4	medium	83.3			
83	high	15.2	54	medium	71			
58	high	55	31	medium	20.9			
34	high	15.5	50	medium	93			
94	high	20.8	55	medium	9.7			
96	high	49.5	36	medium	40.2			
97	high	9.3	59	medium	32			
26	high	21.9	67	medium	189			
61	high	46.1	39	medium	31.9			
5	high	24	18	medium	2			
11	high	101.4	17	medium	12.5			
19	high	6.6	88	medium	41			
20	high	8.2	44	medium	2			
21	high	24						
27	high	26.7						
60	high	24						
70	high	39.4						
13	high	48						
56	high	17						
53	high	75.7						
37	high	47.8						
99	high	50.5						
48	high	44						
77	high	42.6						
72	high	21.8						
100	high	47						
81	high	2.2						

7.7.4 Data for Figure 4.4: Smoking areas in high socioeconomic areas.

venue	SES	compliance	avgPM$_{2.5}$	venue	SES	compliance	avgPM$_{2.5}$
6	high	compliant	7.3	83	high	non-compliant	15.2
33	high	compliant	12	58	high	non-compliant	55
45	high	compliant	4.5	34	high	non-compliant	15.5
25	high	compliant	16.1	94	high	non-compliant	20.8
76	high	compliant	30.5	96	high	non-compliant	49.5
91	high	compliant	40.8	97	high	non-compliant	9.3
92	high	compliant	16	26	high	non-compliant	21.9
93	high	compliant	9.7	61	high	non-compliant	46.1
43	high	compliant	18.3	5	high	non-compliant	24
2	high	compliant	9	11	high	non-compliant	101.4
8	high	compliant	16.9	19	high	non-compliant	6.6
52	high	compliant	17.9	20	high	non-compliant	8.2
16	high	compliant	33.3	21	high	non-compliant	24
7	high	compliant	29.6	27	high	non-compliant	26.7
57	high	compliant	14	60	high	non-compliant	24
				70	high	non-compliant	39.4
				13	high	non-compliant	48
				56	high	non-compliant	17
				53	high	non-compliant	75.7
				37	high	non-compliant	47.8
				99	high	non-compliant	50.5
				48	high	non-compliant	44
				77	high	non-compliant	42.6
				72	high	non-compliant	21.8
				100	high	non-compliant	47
				81	high	non-compliant	2.2

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	18.39333333	34.00769231
Variance	110.7120952	519.4127385
Observations	15	26
Hypothesized Mean Difference	0	
df	38	
t Stat	-2.98524683	
P(T<=t) one-tail	0.002467529	
t Critical one-tail	1.68595446	
P(T<=t) two-tail	0.004935058	
t Critical two-tail	2.024394164	

7.7.5 Data for Figure 4.5: Smoking areas in medium socioeconomic areas.

venue	SES	compliance	avg$PM_{2.5}$	venue	SES	compliance	avg$PM_{2.5}$
84	medium	compliant	13.2	4	medium	non-compliant	83.3
82	medium	compliant	34.9	54	medium	non-compliant	71
29	medium	compliant	16	31	medium	non-compliant	20.9
49	medium	compliant	34.8	50	medium	non-compliant	93
14	medium	compliant	5.8	55	medium	non-compliant	9.7
79	medium	compliant	5.1	36	medium	non-compliant	40.2
35	medium	compliant	8.1	59	medium	non-compliant	32
98	medium	compliant	27.1	67	medium	non-compliant	189
42	medium	compliant	2	39	medium	non-compliant	31.9
3	medium	compliant	28.3	18	medium	non-compliant	2
23	medium	compliant	1.4	17	medium	non-compliant	12.5
1	medium	compliant	17	88	medium	non-compliant	41
15	medium	compliant	4	44	medium	non-compliant	2
9	medium	compliant	15				

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	15.19285714	48.34615385
Variance	140.3299451	2666.511026
Observations	14	13
Hypothesized Mean Difference	0	
df	13	
t Stat	-2.260301326	
P(T<=t) one-tail	0.020804028	
t Critical one-tail	1.770933396	
P(T<=t) two-tail	0.041608056	
t Critical two-tail	2.160368656	

7.7.6 Data from Figure 4.8: Smoking area location within Dublin.

City Centre:

venue	location	compliance	$avgPM_{2.5}$	venue	location	compliance	$avgPM_{2.5}$
76	city centre	compliant	30.5	96	city centre	non-compliant	49.5
91	city centre	compliant	40.8	97	city centre	non-compliant	9.3
92	city centre	compliant	16	61	city centre	non-compliant	46.1
93	city centre	compliant	9.7	11	city centre	non-compliant	101.4
2	city centre	compliant	9	19	city centre	non-compliant	6.6
57	city centre	compliant	14	20	city centre	non-compliant	8.2
35	city centre	compliant	8.1	21	city centre	non-compliant	24
98	city centre	compliant	27.1	72	city centre	non-compliant	21.8
42	city centre	compliant	2	100	city centre	non-compliant	47
		avg:	**17.5**	81	city centre	non-compliant	2.2
		9/26	**35%**	58	city centre	non-compliant	55
				94	city centre	non-compliant	20.8
				60	city centre	non-compliant	24
				70	city centre	non-compliant	39.4
				37	city centre	non-compliant	47.8
				99	city centre	non-compliant	50.5
				77	city centre	non-compliant	42.6
						avg:	**35.1**
						17/26	**65%**

Suburban:

venue	location	compliance	avgPM$_{2.5}$	venue	location	compliance	avgPM$_{2.5}$
33	suburban	compliant	12	34	suburban	non-compliant	15.5
45	suburban	compliant	4.5	26	suburban	non-compliant	21.9
25	suburban	compliant	16.1	5	suburban	non-compliant	24
8	suburban	compliant	16.9	27	suburban	non-compliant	26.7
52	suburban	compliant	17.9	13	suburban	non-compliant	48
16	suburban	compliant	33.3	53	suburban	non-compliant	75.7
7	suburban	compliant	29.6	48	suburban	non-compliant	44
28	suburban	compliant	28	87	suburban	non-compliant	114.4
84	suburban	compliant	13.2	62	suburban	non-compliant	101
82	suburban	compliant	34.9	41	suburban	non-compliant	40.2
29	suburban	compliant	16	10	suburban	non-compliant	18.5
49	suburban	compliant	34.8	89	suburban	non-compliant	59
14	suburban	compliant	5.8	54	suburban	non-compliant	71
79	suburban	compliant	5.1	31	suburban	non-compliant	20.9
3	suburban	compliant	28.3	50	suburban	non-compliant	93
23	suburban	compliant	1.4	55	suburban	non-compliant	9.7
1	suburban	compliant	17	59	suburban	non-compliant	32
15	suburban	compliant	4	67	suburban	non-compliant	189
9	suburban	compliant	15	39	suburban	non-compliant	31.9
6	suburban	compliant	7.3	17	suburban	non-compliant	12.5
43	suburban	compliant	18.3	44	suburban	non-compliant	2
		avg:	**17.1**	83	suburban	non-compliant	15.2
		21/49	**43%**	56	suburban	non-compliant	17
				30	suburban	non-compliant	1.8
				4	suburban	non-compliant	83.3
				36	suburban	non-compliant	40.2
				18	suburban	non-compliant	2
				88	suburban	non-compliant	41
						avg:	44.7
						28/49	**57%**

7.7.7 Data from section 4.1.2: Smoking area perimeter materials

venue	avg$PM_{2.5}$	perimeter>50	venue	avg$PM_{2.5}$	perimeter>50
33	12	no	6	7.3	yes
45	4.5	no	25	16.1	yes
92	16	no	76	30.5	yes
93	9.7	no	91	40.8	yes
2	9	no	43	18.3	yes
8	16.9	no	57	14	yes
52	17.9	no	14	5.8	yes
16	33.3	no	35	8.1	yes
7	29.6	no	98	27.1	yes
28	28	no	83	15.2	yes
84	13.2	no	58	55	yes
82	34.9	no	34	15.5	yes
29	16	no	94	20.8	yes
49	34.8	no	96	49.5	yes
79	5.1	no	97	9.3	yes
42	2	no	26	21.9	yes
3	28.3	no	61	46.1	yes
23	1.4	no	5	24	yes
1	17	no	11	101.4	yes
15	4	no	19	6.6	yes
9	15	no	20	8.2	yes
			21	24	yes
			27	26.7	yes
			60	24	yes
			70	39.4	yes
			13	48	yes
			56	17	yes
			53	75.7	yes
			37	47.8	yes
			99	50.5	yes
			48	44	yes
			77	42.6	yes
			72	21.8	yes
			100	47	yes
			81	2.2	yes
			87	114.4	yes
			62	101	yes
			30	1.8	yes
			41	40.2	yes
			10	18.5	yes
			89	59	yes
			4	83.3	yes

			54	71	yes
			31	20.9	yes
			50	93	yes
			55	9.7	yes
			36	40.2	yes
			59	32	yes
			67	189	yes
			39	31.9	yes
			18	2	yes
			17	12.5	yes
			88	41	yes
			44	2	yes

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	16.6	37.32593
Variance	120.29	1192.591
Observations	21	54
Hypothesized Mean Difference	0	
df	71	
t Stat	-3.92997	
P(T<=t) one-tail	9.75E-05	
t Critical one-tail	1.6666	
P(T<=t) two-tail	0.0002	
t Critical two-tail	1.993943	

7.7.8 *Data from Table 4.2: Did perimeter material effect average $PM_{2.5}$ within smoking areas.*

venue	walltype	avg$PM_{2.5}$
33	combination	12
6	combination	7.3
76	combination	30.5
14	combination	5.8
35	combination	8.1
98	combination	27.1
57	combination	14
4	combination	83.3
55	combination	9.7
21	combination	24
53	combination	75.7
100	combination	47
67	combination	189
39	combination	31.9
70	combination	39.4
56	combination	17
72	combination	21.8
27	combination	26.7
18	combination	2
17	combination	12.5
87	permanent wall	114.4
29	permanent wall	16
28	permanent wall	28
49	permanent wall	34.8
84	permanent wall	13.2
8	permanent wall	16.9
9	permanent wall	15
25	permanent wall	16.1
43	permanent wall	18.3
23	permanent wall	1.4
52	permanent wall	17.9
16	permanent wall	33.3
15	permanent wall	4
26	permanent wall	21.9
11	permanent wall	101.4
30	permanent wall	1.8
41	permanent wall	40.2
13	permanent wall	48
81	permanent wall	2.2
61	permanent wall	46.1
5	permanent wall	24

walltype	avg$PM_{2.5}$
hedge	9.7
hedge	4.5
hedge	17
none	16
none	9
none	2

54	permanent wall	71
31	permanent wall	20.9
50	permanent wall	93
20	permanent wall	8.2
36	permanent wall	40.2
59	permanent wall	32
60	permanent wall	24
37	permanent wall	47.8
99	permanent wall	50.5
48	permanent wall	44
77	permanent wall	42.6
44	permanent wall	2
83	permanent wall	15.2
58	permanent wall	55
34	permanent wall	15.5
94	permanent wall	20.8
96	permanent wall	49.5
62	permanent wall	101
19	permanent wall	6.6
88	permanent wall	41
89	permanent wall	59
3	glass	28.3
79	glass	5.1
82	glass	34.9
91	glass	40.8
7	glass	29.6
97	glass	9.3
10	glass	18.5

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	33.42028986	9.7
Variance	1012.095171	35.96
Observations	69	6
Hypothesized Mean Difference	0	
df	41	
t Stat	5.2184357	
P(T<=t) one-tail	2.77025E-06	
t Critical one-tail	1.682878002	
P(T<=t) two-tail	5.5405E-06	
t Critical two-tail	2.01954097	

t-Test excluding outlier 189 µg/m^3

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	31.13235294	9.7
Variance	660.6189377	35.96
Observations	68	6
Hypothesized Mean Difference	0	
df	29	
t Stat	5.407605663	
P(T<=t) one-tail	4.08716E-06	
t Critical one-tail	1.699127027	
P(T<=t) two-tail	8.17432E-06	
t Critical two-tail	2.045229642	

7.7.9 Data from Figure 4.10: A comparison of smoking areas by their perimeter and the effect they had on average $PM_{2.5}$ levels.

venue	walltype	Perimeter >50	avgPM2.5	venue	walltype	Perimeter >50	avgPM2.5
23	permanent wall	no	1.4	43	permanent wall	yes	18.3
16	permanent wall	no	33.3	41	permanent wall	yes	40.2
15	permanent wall	no	4	13	permanent wall	yes	48
52	permanent wall	no	17.9	36	permanent wall	yes	40.2
29	permanent wall	no	16	59	permanent wall	yes	32
28	permanent wall	no	28	60	permanent wall	yes	24
49	permanent wall	no	34.8	94	permanent wall	yes	20.8
84	permanent wall	no	13.2	88	permanent wall	yes	41
8	permanent wall	no	16.9	25	permanent wall	yes	16.1
9	permanent wall	no	15	87	permanent wall	yes	114.4
				26	permanent wall	yes	21.9
				11	permanent wall	yes	101.4
				30	permanent wall	yes	1.8
				81	permanent wall	yes	2.2
				61	permanent wall	yes	46.1
				5	permanent wall	yes	24
				54	permanent wall	yes	71
				31	permanent wall	yes	20.9
				50	permanent wall	yes	93
				20	permanent wall	yes	8.2
				37	permanent wall	yes	47.8
				99	permanent wall	yes	50.5
				48	permanent wall	yes	44
				77	permanent wall	yes	42.6

				44	permanent wall	yes	2
				83	permanent wall	yes	15.2
				58	permanent wall	yes	55
				34	permanent wall	yes	15.5
				96	permanent wall	yes	49.5
				62	permanent wall	yes	101
				19	permanent wall	yes	6.6
				89	permanent wall	yes	59

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	18.05	39.81875
Variance	125.0138889	907.1286694
Observations	10	32
Hypothesized Mean Difference	0	
df	39	
t Stat	-3.4059787	
P(T<=t) one-tail	0.000770388	
t Critical one-tail	1.684875122	
P(T<=t) two-tail	0.002	
t Critical two-tail	2.02269092	

Glass perimeters:

venue	walltype	perimeter>50	$avgPM_{2.5}$	venue	walltype	perimeter>50	$avgPM_{2.5}$
91	glass	yes	40.8	7	glass	no	29.6
97	glass	yes	9.3	3	glass	no	28.3
10	glass	yes	18.5	79	glass	no	5.1
				82	glass	no	34.9

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	22.86666667	24.475
Variance	262.3633333	174.9891667
Observations	3	4
Hypothesized Mean Difference	0	
df	4	
t Stat	-0.14041266	
P(T<=t) one-tail	0.447560415	
t Critical one-tail	2.131846786	
P(T<=t) two-tail	0.895120829	
t Critical two-tail	2.776445105	

7.7.10 Data from Figure 4.11: Average $PM_{2.5}$ in non-compliant smoking areas categorised by the perimeter materials.

venue	walltype	avgPM2.5	compliance	venue	walltype	avgPM2.5	compliance
41	permanent wall	40.2	non-compliant	4	combination	83.3	non-compliant
13	permanent wall	48	non-compliant	21	combination	24	non-compliant
36	permanent wall	40.2	non-compliant	100	combination	47	non-compliant
59	permanent wall	32	non-compliant	72	combination	21.8	non-compliant
60	permanent wall	24	non-compliant	55	combination	9.7	non-compliant
94	permanent wall	20.8	non-compliant	53	combination	75.7	non-compliant
88	permanent wall	41	non-compliant	67	combination	189	non-compliant
87	permanent wall	114.4	non-compliant	39	combination	31.9	non-compliant
26	permanent wall	21.9	non-compliant	70	combination	39.4	non-compliant
11	permanent wall	101.4	non-compliant	56	combination	17	non-compliant
30	permanent wall	1.8	non-compliant	27	combination	26.7	non-compliant
81	permanent wall	2.2	non-compliant	18	combination	2	non-compliant
61	permanent wall	46.1	non-compliant	17	combination	12.5	non-compliant
5	permanent wall	24	non-compliant				
54	permanent wall	71	non-compliant				
31	permanent wall	20.9	non-compliant				
50	permanent wall	93	non-compliant				
20	permanent wall	8.2	non-compliant				
37	permanent wall	47.8	non-compliant				
99	permanent wall	50.5	non-compliant				
48	permanent wall	44	non-compliant				
77	permanent wall	42.6	non-compliant				
44	permanent wall	2	non-compliant				
83	permanent wall	15.2	non-compliant				
58	permanent wall	55	non-compliant				

34	permanent wall	15.5	non-compliant
96	permanent wall	49.5	non-compliant
62	permanent wall	101	non-compliant
19	permanent wall	6.6	non-compliant
89	permanent wall	59	non-compliant

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	41.32666667	44.61538
Variance	931.9702989	2466.658
Observations	30	13
Hypothesized Mean Difference	0	
df	16	
t Stat	-0.22131897	
P(T<=t) one-tail	0.413821947	
t Critical one-tail	1.745883676	
P(T<=t) two-tail	0.827643893	
t Critical two-tail	2.119905299	

Without outlier within the combination wall type 189 µg/m^3:

venue	walltype	avgPM2.5	compliance
4	combination	83.3	non-compliant
21	combination	24	non-compliant
100	combination	47	non-compliant
72	combination	21.8	non-compliant
55	combination	9.7	non-compliant
53	combination	75.7	non-compliant
39	combination	31.9	non-compliant
70	combination	39.4	non-compliant
56	combination	17	non-compliant
27	combination	26.7	non-compliant
18	combination	2	non-compliant
17	combination	12.5	non-compliant

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	41.32666667	32.58333333
Variance	931.9702989	637.7942424
Observations	30	12
Hypothesized Mean Difference	0	
df	24	
t Stat	0.95275624	
P(T<=t) one-tail	0.175105714	
t Critical one-tail	1.71088208	
P(T<=t) two-tail	0.35021143	
t Critical two-tail	2.063898562	

7.7.11 Data from figure 4.12: The presence of a roof effected $PM_{2.5}$ concentrations.

venue	roofpresent	roof	avgPM2.5	venue	roofpresent	roof	avgPM2.5
7	no	no roof	29.6	33	yes	awning-half	12
45	no	no roof	4.5	3	yes	awning-closed	28.3
1	no	no roof	17	79	yes	awning-half	5.1
42	no	no roof	2	82	yes	fixed-full	34.9
23	no	no roof	1.4	93	yes	awning-closed	9.7
52	no	no roof	17.9	92	yes	awning-closed	16
16	no	no roof	33.3	2	yes	awning-half	9
15	no	no roof	4	29	yes	fixed-full	16
6	no	no roof	7.3	28	yes	fixed-full	28
76	no	no roof	30.5	49	yes	fixed-full	34.8
14	no	no roof	5.8	84	yes	fixed-half	13.2
35	no	no roof	8.1	8	yes	fixed-half	16.9
98	no	no roof	27.1	9	yes	fixed-half	15
57	no	no roof	14	4	yes	awning-closed	83.3
91	no	no roof	40.8	55	yes	awning-closed	9.7
25	no	no roof	16.1	21	yes	awning-closed	24
43	no	no roof	18.3	53	yes	awning-closed	75.7
				100	yes	awning-closed	47
				67	yes	fixed-full	189
				39	yes	fixed-full	31.9
				70	yes	fixed-full	39.4
				56	yes	fixed-full	17
				72	yes	fixed-full	21.8
				27	yes	fixed-half	26.7
				18	yes	fixed-half/awning-closed	2
				17	yes	fixed-half/awning-closed	12.5
				97	yes	awning-closed	9.3
				10	yes	fixed-full	18.5
				87	yes	awning-half	114.4
				26	yes	awning-closed	21.9
				11	yes	awning-closed	101.4

				30	yes	awning-closed	1.8
				41	yes	awning-closed	40.2
				13	yes	awning-closed	48
				81	yes	awning-closed	2.2
				61	yes	fixed-full	46.1
				5	yes	fixed-full	24
				54	yes	fixed-full	71
				31	yes	fixed-full	20.9
				50	yes	fixed-full	93
				20	yes	fixed-full	8.2
				36	yes	fixed-full	40.2
				59	yes	fixed-full	32
				60	yes	fixed-full	24
				37	yes	fixed-full	47.8
				99	yes	fixed-full	50.5
				48	yes	fixed-full	44
				77	yes	fixed-full	42.6
				44	yes	fixed-full	2
				83	yes	fixed-half	15.2
				58	yes	fixed-half	55
				34	yes	fixed-half	15.5
				94	yes	fixed-half	20.8
				96	yes	fixed-half	49.5
				62	yes	fixed-half	101
				19	yes	fixed-half	6.6
				88	yes	fixed-half	41
				89	yes	fixed-half	59

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	16.33529412	35.97413793
Variance	148.2686765	1134.479846
Observations	17	58
Hypothesized Mean Difference	0	
df	70	
t Stat	-3.69286373	
P(T<=t) one-tail	0.000217887	
t Critical one-tail	1.666914479	
P(T<=t) two-tail	0.000435774	
t Critical two-tail	1.994437112	

7.7.12 Data from 4.1.4 Other sources of $PM_{2.5}$ within the smoking areas:

Possible other source of $PM_{2.5}$	**Average $PM_{2.5}$ within smoking areas (µg/m^3)**
Gas heaters (n= 39)	34.3
Close to heavy traffic (n= 11)	27.1
> one other source e.g. fire pit, cooking vent and traffic (n= 8)	24.3
No other source noted (n= 17)	31.3

7.7.13 Data from table 4.7: Effect of public health guidelines on food service within smoking areas.

venue	month	year	food	venue	month	year	food
93	1	2020	Food served	23	7	2020	Food served
92	1	2020	Food served	2	7	2020	Food served
91	1	2020	Food served	17	7	2020	Food served
79	1	2020	No food served	42	7	2020	Food served
60	2	2020	Food served	3	7	2020	No food served
70	2	2020	Food served	77	8	2020	Food served
41	2	2020	Food served	37	8	2020	Food served
43	2	2020	No food served	52	8	2020	Food served
98	3	2020	Food served	10	8	2020	Food served
13	3	2020	Food served	48	8	2020	Food served
35	3	2020	Food served	99	8	2020	Food served
56	3	2020	No food served	53	8	2020	Food served
			9/12	8	8	2020	No food served
			75%	16	8	2020	No food served
				44	9	2020	Food served
				15	9	2020	Food served
				7	9	2020	Food served
				1	9	2020	Food served
				72	9	2020	Food served
				88	9	2020	Food served
				89	9	2020	Food served
				57	10	2020	Food served
				81	10	2020	Food served
				9	10	2020	Food served
				100	10	2020	Food served
							22/25
							88%

7.7.14 Data from table 4.8: Mean $PM_{2.5}$ in non-smoking area of venue versus smoking area.

venue	avgPMinside (µg/m^3)	avg$PM_{2.5}$ (µg/m^3)
79	0.3	5.1
28	1	28
1	1.2	17
18	1.5	2
19	2	6.6
15	2	4
34	2.2	15.5
52	2.7	17.9
35	2.8	8.1
88	2.8	41
93	3	9.7
14	3.1	5.8
44	3.3	2
23	3.5	1.4
72	3.6	21.8
76	4.5	30.5
3	4.6	28.3
45	5	4.5
2	5	9
42	5	2
92	5.3	16
48	5.3	44
58	6	55
59	6	32
97	6.1	9.3
20	6.2	8.2
8	6.2	16.9
53	6.3	75.7
55	6.5	9.7
7	6.6	29.6
84	6.6	13.2
99	6.7	50.5
10	6.7	18.5
98	7.1	27.1
60	7.6	24
27	8	26.7
56	8	17
30	8.7	1.8
50	9.2	93
17	9.2	12.5
36	9.4	40.2

11	9.5	101.4
70	9.5	39.4
33	10	12
39	10	31.9
16	10.1	33.3
37	10.4	47.8
6	10.6	7.3
54	10.6	71
91	11	40.8
13	11	48
41	11	40.2
62	11.6	101
5	11.8	24
26	12.2	21.9
31	12.5	20.9
49	13.7	34.8
96	15.3	49.5
77	17.7	42.6
29	19	16
83	19.2	15.2
89	20.6	59
43	20.9	18.3
25	21	16.1
94	25.8	20.8
87	28.4	114.4
61	29	46.1
4	33.6	83.3
21	46.3	24
67	50.2	189
82	52	34.9
57	NA	14
100	NA	47
81	NA	2.2
9	NA	15
avg	**11.0**	**31.5**
max	**52**	**189**
min	**0.3**	**1.4**

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	11.00422535	31.52266667
Variance	114.553839	974.4339387
Observations	71	75
Hypothesized Mean Difference	0	
df	92	
t Stat	-5.368839243	
P(T<=t) one-tail	2.95439E-07	
t Critical one-tail	1.661585397	
P(T<=t) two-tail	5.90877E-07	
t Critical two-tail	1.986086317	

7.7.15 Data from Table 4.10: Smoking area concentrations categorised by applying the EPA AQIH

Good:

AQI	venue	SES	location	avg$PM_{2.5}$	compliant
1	23	medium	suburban	1.4	compliant
1	30	low	suburban	1.8	non-compliant
1	44	medium	suburban	2	non-compliant
1	18	medium	suburban	2	non-compliant
1	42	medium	city centre	2	compliant
1	81	high	city centre	2.2	non-compliant
1	15	medium	suburban	4	compliant
1	45	high	suburban	4.5	compliant
1	79	medium	suburban	5.1	compliant
1	14	medium	suburban	5.8	compliant
1	19	high	city centre	6.6	non-compliant
1	6	high	suburban	7.3	compliant
1	35	medium	city centre	8.1	compliant
1	20	high	city centre	8.2	non-compliant
1	2	high	city centre	9	compliant
1	97	high	city centre	9.3	non-compliant
1	55	medium	suburban	9.7	non-compliant
1	93	high	city centre	9.7	compliant
2	33	high	suburban	12	compliant
2	17	medium	suburban	12.5	non-compliant
2	84	medium	suburban	13.2	compliant
2	57	high	city centre	14	compliant
2	9	medium	suburban	15	compliant
2	83	high	suburban	15.2	non-compliant
2	34	high	suburban	15.5	non-compliant
2	29	medium	suburban	16	compliant
2	92	high	city centre	16	compliant
2	25	high	suburban	16.1	compliant
2	8	high	suburban	16.9	compliant
2	1	medium	suburban	17	compliant
2	56	high	suburban	17	non-compliant
2	52	high	suburban	17.9	compliant
2	43	high	suburban	18.3	compliant
2	10	low	suburban	18.5	non-compliant
2	94	high	city centre	20.8	non-compliant
2	31	medium	suburban	20.9	non-compliant
2	72	high	city centre	21.8	non-compliant
2	26	high	suburban	21.9	non-compliant
3	5	high	suburban	24	non-compliant
3	21	high	city centre	24	non-compliant

3	60	high	city centre	24	non-compliant
3	27	high	suburban	26.7	non-compliant
3	98	medium	city centre	27.1	compliant
3	28	low	suburban	28	compliant
3	3	medium	suburban	28.3	compliant
3	7	high	suburban	29.6	compliant
3	76	high	city centre	30.5	compliant
3	39	medium	suburban	31.9	non-compliant
3	59	medium	suburban	32	non-compliant
3	16	high	suburban	33.3	compliant
3	49	medium	suburban	34.8	compliant
3	82	medium	suburban	34.9	compliant

Fair:

AQI	venue	SES	location	avgPM$_{2.5}$	compliant
4	70	high	city centre	39.4	non-compliant
4	36	medium	suburban	40.2	non-compliant
4	41	low	suburban	40.2	non-compliant
4	91	high	city centre	40.8	compliant
4	88	medium	suburban	41	non-compliant
5	77	high	city centre	42.6	non-compliant
5	48	high	suburban	44	non-compliant
5	61	high	city centre	46.1	non-compliant
5	100	high	city centre	47	non-compliant
5	37	high	city centre	47.8	non-compliant
6	13	high	suburban	48	non-compliant
6	96	high	city centre	49.5	non-compliant
6	99	high	city centre	50.5	non-compliant

Poor:

AQI	venue	SES	location	avgPM$_{2.5}$	compliant
7	58	high	city centre	55	non-compliant
8	89	low	suburban	59	non-compliant

Very poor:

AQI	venue	SES	location	avg$PM_{2.5}$	compliant
10	54	medium	suburban	71	non-compliant
10	53	high	suburban	75.7	non-compliant
10	4	medium	suburban	83.3	non-compliant
10	50	medium	suburban	93	non-compliant
10	62	low	suburban	101	non-compliant
10	11	high	city centre	101.4	non-compliant
10	87	low	suburban	114.4	non-compliant
10	67	medium	suburban	189	non-compliant

7.7.16 Data from section 4.1.7: A closer look at smokers recorded in the smoking areas

venue	avgsmokers	avg$PM_{2.5}$
6	15	7.3
83	3	15.2
33	3	12
58	9	55
45	3	4.5
25	1	16.1
34	1	15.5
94	3	20.8
96	6	49.5
97	4	9.3
76	9	30.5
26	3	21.9
61	5	46.1
5	3.8	24
11	31	101.4
19	39	6.6
20	2	8.2
21	3	24
27	2	26.7
91	2	40.8
92	1	16
93	1	9.7
60	9	24
70	5	39.4
43	4	18.3
13	5	48
56	26	17
2	2	9
8	5.8	16.9
52	0.5	17.9
53	6.3	75.7
37	7.3	47.8
99	11.8	50.5
16	2.8	33.3
48	2.3	44
77	5	42.6
72	2.2	21.8
7	2	29.6
57	1	14
100	2	47
81	0	2.2
87	11	114.4

28	9	28
62	3	101
30	4	1.8
41	5	40.2
10	1.5	18.5
89	7.5	59
84	2	13.2
4	28	83.3
82	9	34.9
29	5	16
54	10	71
31	3	20.9
49	5	34.8
50	4	93
55	3	9.7
36	2	40.2
59	4	32
67	2	189
39	2	31.9
18	2	2
14	3	5.8
79	1.5	5.1
35	2	8.1
98	4	27.1
42	1	2
3	2	28.3
23	3	1.4
17	5.5	12.5
88	5	41
1	1.5	17
15	1.3	4
44	0.8	2
9	1.8	15

Correlation:

	Column 1	*Column 2*
Column 1	1	
Column 2	0.240921	1

7.7.17 Data from section 4.1.8: Seasonal effects

venue	season	avgPM2.5	venue	season	avgPM2.5
98	Spring	27.1	58	Summer	55
33	Spring	12	76	Summer	30.5
84	Spring	13.2	37	Summer	47.8
13	Spring	48	77	Summer	42.6
83	Spring	15.2	29	Summer	16
56	Spring	17	34	Summer	15.5
6	Spring	7.3	26	Summer	21.9
4	Spring	83.3	87	Summer	114.4
35	Spring	8.1	2	Summer	9
82	Spring	34.9	96	Summer	49.5
			45	Summer	4.5
			8	Summer	16.9
			52	Summer	17.9
			3	Summer	28.3
			23	Summer	1.4
			48	Summer	44
			10	Summer	18.5
			17	Summer	12.5
			42	Summer	2
			94	Summer	20.8
			99	Summer	50.5
			16	Summer	33.3
			53	Summer	75.7
			97	Summer	9.3
			25	Summer	16.1
venue	**season**	**avgPM2.5**	**venue**	**season**	**avgPM2.5**
57	Autumn	14	60	Winter	24
44	Autumn	2	70	Winter	39.4
11	Autumn	101.4	14	Winter	5.8
19	Autumn	6.6	79	Winter	5.1
20	Autumn	8.2	41	Winter	40.2
100	Autumn	47	43	Winter	18.3
81	Autumn	2.2	91	Winter	40.8
28	Autumn	28	92	Winter	16
49	Autumn	34.8	93	Winter	9.7
9	Autumn	15			
5	Autumn	24			
27	Autumn	26.7			
54	Autumn	71			
31	Autumn	20.9			

50	Autumn	93			
55	Autumn	9.7			
59	Autumn	32			
67	Autumn	189			
39	Autumn	31.9			
30	Autumn	1.8			
36	Autumn	40.2			
18	Autumn	2			
61	Autumn	46.1			
7	Autumn	29.6			
15	Autumn	4			
62	Autumn	101			
89	Autumn	59			
21	Autumn	24			
1	Autumn	17			
72	Autumn	21.8			

7.7.18 Data from figure 4.28: Observed changes from 2019 to 2020.

venue	**year**	**avgPM$_{2.5}$**	**venue**	**year**	**avgPM$_{2.5}$**
6	2019	7.3	91	2020	40.8
83	2019	15.2	92	2020	16
33	2019	12	93	2020	9.7
58	2019	55	60	2020	24
45	2019	4.5	70	2020	39.4
25	2019	16.1	43	2020	18.3
34	2019	15.5	13	2020	48
94	2019	20.8	56	2020	17
96	2019	49.5	2	2020	9
97	2019	9.3	8	2020	16.9
76	2019	30.5	52	2020	17.9
26	2019	21.9	53	2020	75.7
61	2019	46.1	37	2020	47.8
5	2019	24	99	2020	50.5
11	2019	101.4	16	2020	33.3
19	2019	6.6	48	2020	44
20	2019	8.2	77	2020	42.6
21	2019	24	72	2020	21.8
27	2019	26.7	7	2020	29.6
87	2019	114.4	57	2020	14
28	2019	28	100	2020	47
62	2019	101	81	2020	2.2
30	2019	1.8	41	2020	40.2
84	2019	13.2	10	2020	18.5
4	2019	83.3	89	2020	59
82	2019	34.9	79	2020	5.1
29	2019	16	35	2020	8.1
54	2019	71	98	2020	27.1
31	2019	20.9	42	2020	2
49	2019	34.8	3	2020	28.3
50	2019	93	23	2020	1.4
55	2019	9.7	17	2020	12.5
36	2019	40.2	88	2020	41
59	2019	32	1	2020	17
67	2019	189	15	2020	4
39	2019	31.9	44	2020	2
18	2019	2	9	2020	15
14	2019	5.8			

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	37.30263158	25.58648649
Variance	1550.530533	337.9212012
Observations	38	37
Hypothesized Mean Difference	0	
df	53	
t Stat	1.657967259	
P(T<=t) one-tail	0.051616027	
t Critical one-tail	1.674116237	
P(T<=t) two-tail	0.103232053	
t Critical two-tail	2.005745995	

7.7.19 Data for figure 4.29: Did time of day effect average $PM_{2.5}$

venue	**time**	**avg$PM_{2.5}$**	**venue**	**time**	**avg$PM_{2.5}$**
6	day	7.3	83	night	15.2
94	day	20.8	33	night	12
97	day	9.3	58	night	55
76	day	30.5	45	night	4.5
21	day	24	25	night	16.1
91	day	40.8	34	night	15.5
92	day	16	96	night	49.5
93	day	9.7	26	night	21.9
60	day	24	61	night	46.1
43	day	18.3	5	night	24
13	day	48	11	night	101.4
2	day	9	19	night	6.6
16	day	33.3	20	night	8.2
72	day	21.8	27	night	26.7
7	day	29.6	70	night	39.4
57	day	14	56	night	17
100	day	47	8	night	16.9
41	day	40.2	52	night	17.9
10	day	18.5	53	night	75.7
4	day	83.3	37	night	47.8
36	day	40.2	99	night	50.5
59	day	32	48	night	44
35	day	8.1	77	night	42.6
98	day	27.1	81	night	2.2
42	day	2	87	night	114.4
23	day	1.4	28	night	28
88	day	41	62	night	101
1	day	17	30	night	1.8
15	day	4	89	night	59
			84	night	13.2
			82	night	34.9
			29	night	16
			54	night	71
			31	night	20.9
			49	night	34.8
			50	night	93
			55	night	9.7
			67	night	189
			39	night	31.9
			18	night	2
			14	night	5.8
			79	night	5.1

			3	night	28.3
			17	night	12.5
			44	night	2
			9	night	15

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	24.76551724	35.7826087
Variance	314.185197	1358.934357
Observations	29	46
Hypothesized Mean Difference	0	
df	69	
t Stat	- 1.733824686	
P(T<=t) one-tail	0.043707728	
t Critical one-tail	1.667238549	
P(T<=t) two-tail	0.087415455	
t Critical two-tail	1.994945415	

7.7.20 Data from table 4.12: Spirometry test results

FEV1	**Pretest % predicted**	**pretest value**	**Posttest % predicted**	**posttest value**
HA01	102	3.57	100	3.48
HA02	96	3.28	100	3.37
HA03	91	3.54	89	3.45
HA04	121	2.36	121	2.36
HA05	90	4.2	89	4.13
HA06	122	2.64	122	2.64
HA07	102	4.5	103	4.52
HA08	81	2.65	74	2.45
HA09	95	4.22	98	4.35
HA10	98	4.58	98	4.54
Average:	**99.8**		**99.4**	

t-Test: Paired Two Sample for Means

	Variable 1	*Variable 2*
Mean	99.8	99.4
Variance	168.8444444	206.26667
Observations	10	10
Pearson Correlation	0.980483831	
Hypothesized Mean Difference	0	
df	9	
t Stat	0.418039809	
P(T<=t) one-tail	0.342857887	
t Critical one-tail	1.833112933	
P(T<=t) two-tail	0.685715774	
t Critical two-tail	2.262157163	

FVC	**Pretest % predicted**	**pretest value**	**Posttest % predicted**	**posttest value**
HA01	109	4.35	97	3.89
HA02	94	3.65	96	3.72
HA03	91	4.45	86	4.22
HA04	117	2.73	118	2.75
HA05	84	4.68	83	4.6
HA06	126	3.22	118	3.02
HA07	111	5.84	107	5.63
HA08	79	2.97	74	2.79
HA09	82	4.32	94	4.93
HA10	102	5.64	99	5.51
Average	**99.5**		**97.2**	

t-Test: Paired Two Sample for Means

	Variable 1	*Variable 2*
Mean	99.5	97.2
Variance	256.2778	204.6222
Observations	10	10
Pearson Correlation	0.914127	
Hypothesized Mean Difference	0	
df	9	
t Stat	1.119181	
P(T<=t) one-tail	0.146021	
t Critical one-tail	1.833113	
P(T<=t) two-tail	0.292042	
t Critical two-tail	2.262157	

PEF	**Pretest % predicted**	**pretest value**	**Posttest % predicted**	**posttest value**
HA01	103	464	102	460
HA02	100	443	121	530
HA03	121	666	110	605
HA04	119	392	117	388
HA05	90	559	89	550
HA06	144	492	144	497
HA07	104	624	107	640
HA08	111	479	122	483
HA09	106	635	118	707
HA10	101	627	95	590
Average:	109.9		112.5	

t-Test: Paired Two Sample for Means

	Variable 1	*Variable 2*
Mean	109.9	112.5
Variance	226.7667	245.6111
Observations	10	10
Pearson Correlation	0.810025	
Hypothesized Mean Difference	0	
df	9	
t Stat	-0.86645	
P(T<=t) one-tail	0.204373	
t Critical one-tail	1.833113	
P(T<=t) two-tail	0.408747	
t Critical two-tail	2.262157	

CO	Pre exposure	Post exposure
HA01	1	0
HA02	0	0
HA03	2	0
HA04	2	1
HA05	1	2
HA06	3	2
HA07	2	2
HA08	1	1
HA09	0	1
HA10	1	1
Average	1.3	1

t-Test: Paired Two Sample for Means

	Variable 1	*Variable 2*
Mean	1.3	1
Variance	0.9	0.666667
Observations	10	10
Pearson Correlation	0.430331	
Hypothesized Mean Difference	0	
df	9	
t Stat	1	
P(T<=t) one-tail	0.171718	
t Critical one-tail	1.833113	
P(T<=t) two-tail	0.343436	
t Critical two-tail	2.262157	

7.7.21 Data from table 4.13: Manual peak flow tests

PF	Pretest % predicted	Pretest value	During % predicted	During exposure value	Posttest % predicted	Posttest value
HA01	110	490	110	490	110	490
HA02	120	510	99	420	118	500
HA03	111	680	109	670	106	650
HA04	107	370	98	340	107	370
HA05	97	570	94	550	97	570
HA06	136	500	136	500	136	500
HA07	106	650	104	640	99	610
HA08	110	460	110	460	105	440
HA09	114	700	114	700	116	710
HA10	94	600	94	600	94	600
Average	**110.5**		**106.8**		**108.8**	

Pre exposure v post exposure:

t-Test: Paired Two Sample for Means

	Variable 1	*Variable 2*
Mean	110.5	108.8
Variance	137.8333333	150.8444
Observations	10	10
Pearson Correlation	0.970926257	
Hypothesized Mean Difference	0	
df	9	
t Stat	1.824923481	
P(T<=t) one-tail	0.050654381	
t Critical one-tail	1.833112933	
P(T<=t) two-tail	0.101308762	
t Critical two-tail	2.262157163	

Pre exposure v during exposure:

t-Test: Paired Two Sample for Means

	Variable 1	*Variable 2*
Mean	110.5	106.8
Variance	137.8333	155.9556
Observations	10	10
Pearson Correlation	0.849543	
Hypothesized Mean Difference	0	
df	9	
t Stat	1.750475	
P(T<=t) one-tail	0.056979	
t Critical one-tail	1.833113	
P(T<=t) two-tail	0.113958	
t Critical two-tail	2.262157	

List of Employability Skills and Discipline Specific Skills Training

Research Integrity

Understandably compulsory, this module provided valuable information about the responsibilities and expectations of researchers. Lessons on ethics, authorship, plagiarism and public access to research were taught.

Research Methods

This module was undertaken at the beginning of the degree as a solid introduction into the world of post graduate research. It provided the author with a comprehensive approach to reading literature critically, forming a literature review and planning out the research project.

Introduction to Statistics

It was important that statistics were understood in advance of the write up. This module helped with a further understanding by incorporating analysis methods in Rstudio which were ultimately built on in the data visualisation module.

Philosophy of Science and Technology

This module was chosen when the research was underway for this project and the author was interested in broadening their knowledge on the philosophy of science, particularly the theory of epistemology. This was an extremely challenging module which demanded hours of additional study.

Information Retrieval

Chosen due to the focus on research retrieval tools, publication of research and familiarisation with the publication process. In addition to this, emphasis on scholarly profiles was beneficial and provided the author with some valuable connections and visibility in their discipline.

Data Visualisation

This module was chosen because the author was uneducated in visualisation methods. This module was completed during the second year and was an incredibly valuable class for formation of the results chapter. The R programming language with a focus on aesthetics for publication was taught.